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GUIDE BOOK No. 1

EXCURSION *in* Eastern Quebec *and the* Maritime Provinces

PART I

OTTAWA
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Eastern Quebec and the Maritime Provinces

(EXCURSION A 1.)

PART I

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CONTENTS.

PART I.

Part II.

Illustrations to Part I.

Maps.

PAGE.

DRAWINGS AND SECTIONS.

PHOTOGRAPHS.

GENERAL INTRODUCTION.

GEOLOGY.

(G. A. Young.)

The part of Canada lying east of the St. Lawrence river below Quebec city and having a width of about 500 miles (800 km.) in an east and west direction, includes the provinces of Nova Scotia, Prince Edward Island, and New Brunswick, and a part of the province of Quebec. Though presenting a great diversity of physical and geological features, the region as a whole may be regarded as a unit inasmuch as the geological and physical provinces into which the region is divisible, all trend in a northeasterly direction. Having regard, then, to the structural elements, the region may be said to have a width of 375 miles (595 km.) measured from the St. Lawrence on the northwest, to the Atlantic coast of Nova Scotia on the southeast.

One of the more marked physical provinces of the region is the plain bordering the St. Lawrence—the St. Lawrence lowland. A very marked feature to the southwest of Quebec city, this plain to the northeast gradually narrows and is limited to the territory immediately bordering the St. Lawrence on the south. To the southeast, the St. Lawrence lowland merges into an elevated tract of country extending in a general northeasterly direction. Southwest of the latitude of Quebec city, this upland is formed, in Canada, by three rudely parallel ridges which over considerable areas rise above 2,000 feet (600 m.). Proceeding northeastward to a point east of the city of Quebec, this upland, the Notre Dame mountains, sinks to lower and lower elevations, but beyond, to the northeast, it again increases in height, so that in Gaspe peninsula it forms an uplifted area with a general elevation of from 1,000 to 2,000 feet (300 to 600 m.) with peaks rising above 3,500 feet (1,050 m.).

The higher more rugged portion of this upland is bordered on the southwest, in the Gaspe Peninsula, by a plateau-like region extending to the shores of the Bay of Chaleur, and having a general elevation of about 1,000 feet (300 m.). This plateau-like upland extends in a southwest direction through northwestern New Brunswick and continues southward on both sides of the St. John valley where the

general elevation is however, considerably less than 1,000 feet (300 m.).

In New Brunswick, the plateau area is bordered on the southwest by a much more rugged area with numerous peaks rising above 2,000 feet (600 m.). This broken, semi-mountainous tract occupies the central portion of the province. It is bounded on the southwest by a lowland area of about 10,000 square miles (26,000 sq. km.) over which the general elevation is less than 500 feet (150 m.). This lowland reaches on the east, to the Gulf of St. Lawrence, forms the whole of Prince Edward Island, and extends easterly into Nova Scotia along the north side of the Cobequid hills. In New Brunswick, the lowland is bordered on the south by Caledonia mountain, a wide ridge rising steeply from the northwestern shores of the Bay of Fundy and having over a considerable area, a general altitude of about 1,200 feet (360 m.). In Nova Scotia, the upland area of the Cobequid hills forms the southern boundary of the extensive lowland. The Cobequid hills run in an easterly direction from the head of the Bay of Fundy. They have a general elevation in the neighbourhood of 600 to 900 feet (180 to 270 m), and on their south side slope down to Minas Basin, an easterly prolongation of the Bay of Fundy.

The peninsula of Nova Scotia is formed mainly of an upland area extending in a general northeasterly direction and having along its axial line a general elevation of about 1,000 feet (300 m.). On the southeastern side it falls gradually to the ocean, on the northwestern side its slopes are steeper and it is in part, bounded by a lowland area surrounding the Cobequid hills and extending westward into New Brunswick. The island of Cape Breton forms the northeastern extension of the main upland of Nova Scotia, and on this island the upland area, though broken into isolated ridges, attains a maximum altitude of above 1,500 feet (450 m.).

The wide channel of the St. Lawrence on the northwest forms the natural boundary of the region in this direction. To the northwest of the river valley stretches the vast Pre-Cambrian area of the "Canadian Shield" which abruptly rises from the St. Lawrence shores to heights of 1,000 feet (300 m.) and more. At widely separated intervals along the northwest shore, and on Anticosti island and on some of the smaller islands, are displayed

nearly horizontal or gently dipping strata ranging in age from lower Ordovician to uppermost Silurian. The measures rest on the Pre-Cambrian and abut against the edge of the upland area of the Canadian Shield.

Along the southwestern shore of the St. Lawrence, the strata, striking in a northeasterly direction, are closely folded, in a large measure overturned, and are traversed by many dislocations, along some of which the strata from the southeast are thrust over the beds to the northwest. In age these measures range from late Ordovician to Cambrian; they belong to the Quebec group and differ lithologically and faunally from the nearly horizontal strata of the islands and north shore of the St. Lawrence and from which they are separated by a great fault or zone of faulting that strikes in a southeasterly direction beneath the waters of the St. Lawrence as far as the neighbourhood of Quebec city and from there, continuing with the same general direction, runs through the land area to Lake Champlain and beyond.

The band of the Quebec group which borders the St. Lawrence below Quebec, varies in width from 6 miles to 35 miles (9.6 to 56 km.). On the southeast these rocks are bounded by a great area of strata that in the main, range in age from Devonian to Silurian. Such measures form the greater part of the peninsula of Gaspe and, stretching to the southwest from the upper part of Chaleur bay, occupy the northwestern portion of New Brunswick. Along their northwestern boundary, these measures in places overlap the Quebec group strata, in other places have been thrust over them, while along the mountainous axes of the Gaspe peninsula a narrow zone of Palæozoic igneous rocks and deformed strata possibly of Pre-Cambrian age, intervenes.

The strata of this essentially Silurian and Devonian area, are folded along axial lines which, in the southwest, strike to the northeast but which in the Gaspe peninsula swing to an easterly course. In certain districts, the strata lie in open folds, but perhaps over the greater part of the region the folding is closer and in many places the beds are crumpled and highly faulted.

In Gaspe, the Silurian and Devonian measures occupy an area having a breadth of 70 miles (110 km); to the southwest, in New Brunswick, the area is approximately 150 miles (240 km.) wide. In the southeastern part of

this region, in New Brunswick, Ordovician strata are also present, and associated with the sedimentary beds are extrusive and intrusive volcanic rocks and batholitic bodies of Devonian granite. By far the greater part of the region, however, is underlain by marine sediments representing nearly the whole of the Silurian and the lower part of the Devonian systems. In the Gaspe peninsula, are large areas of higher Devonian strata, rich in plant remains.

As already mentioned, the southeastern portion of the above described region is characterized in New Brunswick, by the presence with the Silurian and Devonian, of Ordovician strata and of volcanic rocks and large bodies of granite. This bordering zone stretches southwestward through New Brunswick from Chaleur bay to the Maine boundary, a distance of 175 miles (281 km.), and has an average breadth of about 40 miles (65 km.). In the extreme southwest, this complex projects eastward to the Atlantic coast and there has a total width of about 90 miles (145 km.). Presumably this zone of Silurian and older strata and the associated volcanic and plutonic rocks with a breadth of not much less than 100 miles (160 km.), extends to the northeast to the Gulf of the St. Lawrence, but to the northeast not far from the Maine boundary, these rocks, in part disappear beneath a mantle of Carboniferous measures occupying a triangular stretch of low-lying country having an area of about 10,000 square miles (26,000 sq. k.m.).

The Carboniferous strata of this extensive area, are mainly of Millstone Grit (mid-Carboniferous) age. Except locally along the southern margin, the strata are flat-lying, almost undisturbed. The rocks consist chiefly of sandstones and shales with relatively thin beds of coal. Along the southern margin of the Carboniferous area, older divisions of the Carboniferous are present and locally are much folded and faulted. This area of undisturbed measures is represented to the east on Prince Edward Island and on the Nova Scotia mainland facing Prince Edward Island, but in this eastern district, the essentially undisturbed measures are of late Carboniferous and early Permian age.

The great triangular area of Carboniferous rocks in New Brunswick, is limited, as already stated, on the northwest and on the extreme west and south, by Silurian and older strata associated with and penetrated by volcanic

and plutonic rocks. But along the eastern half of the southern border of the Carboniferous area, the Carboniferous rocks abut against and extend into an area dominantly occupied by Pre-Cambrian rocks with which are associated Cambrian and perhaps younger Palæozhic sediments. This complex forms another of the north-easterly extending zones which so characterize the general region. This area, essentially underlain by Pre-Cambrian rocks, borders the Bay of Fundy coast which apparently truncates the Pre-Cambrian area. In places, along the Bay of Fundy coast, the Pre-Cambrian zone is fringed with Carboniferous strata and it may be that the Bay of Fundy trough has been developed chiefly in Carboniferous and younger measures.

The province of Nova Scotia lies southeast of New Brunswick and is almost completely severed from it by the Bay of Fundy. The peninsula of Nova Scotia, including the mainland and the continuing area of Cape Breton Island to the northeast, has a length, along a nearly due northeast course, of about 360 miles (580 km.) and an average breadth of about 60 miles (95 km.). In this province the main geological structures are less broadly and more irregularly developed than in the region to the northwest and therefore may not be so readily outlined in generalized terms.

The southwestern portion of the peninsula of Nova Scotia is almost entirely occupied by a broadly folded sedimentary series of late Pre-Cambrian age penetrated by large batholiths of granite of Devonian age. These rocks extend to the northeast with a gradually diminishing width, and outcrop along the whole length—270 miles (435 km.)— of the Atlantic coast of the Nova Scotian peninsula. In the southwest these measures are bordered on the northwest foı a distance of about 120 miles (190 km.) by small detached areas of late Silurian and early Devonian strata which in theiı turn are bordered by a narrow strip of Triassic strata forming the Bay of Fundy shore. To the northeast, however, the Pre-Cambrian sediments and their intrusive granites are bordered by Carboniferous strata which, encircling laıge and small areas of older Palæozoic sediments and igneous rocks, extend westward to join the Carboniferous area of New Brunswick. The island of Cape Breton, to the northeast, is in the main underlain by ancient Pre-Cambrian strata occupying

large and small, detached areas which are surrounded and penetrated by Carboniferous measures.

PHYSIOGRAPHY.

(J. W. Goldthwait.)

Eastern Quebec and the Maritime Provinces lie at the northeastern end of the Appalachian Mountain region of eastern United States and Canada. This region, although not generally mountainous at the present time, possesses a complex and crumpled rock structure which can only have been produced by diastrophism. Since Cambrian, Ordovician, Silurian, and Devonian sediments are all involved in the close folds, and partake of the regional metamorphism that characterizes the province, it is evident that the region was very mountainous in Palæozoic time. While the Mesozoic rocks have suffered much less deformation, they too, show that as late as the end of the Jurassic period diastrophism was taking place on a large scale. It is probable then, that at the beginning of the Cretaceous period this whole region was occupied by lofty mountain chains. During the closing part of the Mesozoic, however, subaerial denudation appears to have held sway without interruption from diastrophism. The mountains were slowly but surely reduced to a plain of low relief, or "peneplain". Remnants of this great baselevelled surface of the Cretaceous can be found along the Appalachian system all the way from New Brunswick to Alabama. Locally, in districts remote from the coast, and where stronger rock structures appeared just above the Cretaceous baselevel, the reduction of the surface was incomplete, and many residual mountains or "monadnocks" were left. On the whole, however, the baselevelling was very thorough, planing away the harder rocks as well as the weaker.

This almost complete cycle of denudation was brought to a close at about the beginning of the Tertiary by regional uplifts of continental extent. All along the Appalachian province, in United States and Canada, the Cretaceous peneplain was raised, with more or less warping converting the lowland into an upland. The uplift seems everywhere to have been greatest in the interior and least neaı the coast. By it, the seaward flowing rivers were revived,

and a new cycle of erosion was begun. Where the upland possessed weak rock structures, as in the Carboniferous areas of eastern New Brunswick and the Triassic areas of Nova Scotia and southern New England, the new denudation progressed rapidly, and by mid-Tertiary time broad lowlands had been developed. Meanwhile, wherever weather-resisting rocks predominated, gorges and narrow valleys were cut, dissecting the upland into a rolling hilly country. By the time this second cycle of denudation had been nearly completed in the lowlands, another elevation of the region occurred, attended like the first, by local warping. The lowlands were again carved by streams until a fairly mature topography had been evolved beneath the Tertiary surface.

All this occurred before the Glacial period. With the development of an ice sheet over all northern North America, at the beginning of the Pleistocene, a series of events took place, whose exact nature and sequence, so far as the Maritime Provinces are concerned, are still largely problematical. Most of the region in question was sooner or later covered by the continental ice, and given a new coat of mantle rock or "drift." Portions of the Gaspe peninsula and Nova Scotia may have remained outside the limits of glaciation. No one can say positively, as yet, whether the ice which spread over this region came from the centre east of Hudson bay, or whether there were two or more separate centres of dispersal of the continental glacier within the limits of the Maritime Provinces. From evidence gathered during twenty years of field work, the late Dr. Robert Chalmers came to believe that the more easterly portions of the region, at least, were glaciated solely by ice from the interior of New Brunswick and the Gaspe peninsula, while southern Quebec, only, was reached by ice from the Hudson bay region.

There is much uncertainty, also, about changes of level in land and sea during the Pleistocene. Whatever elevations or subsidences may have gone on in the earlier epochs, it is plain that when the ice sheet finally withdrew from the south coast of the lower St. Lawrence and the Champlain valley, the land stood several hundred feet lower than now. The coast of New England and New Brunswick, likewise, was deeply submerged. The elevation of these coasts to their present position appears to have

commenced as soon as the ice sheet withdrew and to have proceeded steadily and rapidly By this uplift ancient wave built beaches and marine clays containing fossils of characteristic Arctic shellfish, have been raised to altitudes of from 50 to 600 feet (15 to 180 m.) above sea level. Although differential, the movement was remarkably uniform, without any local buckling or dislocation of the geoid surface. Even with this recently acquired altitude, the coast stands lower to-day than it did at the beginning of the Pleistocene; for the larger valleys, the St. Lawrence, Restigouche, and Miramichi, are estuaries, still deeply drowned beneath the sea. More recently there have been minor changes of level along the coast. On the St. Lawrence east of Quebec, through a distance of 400 miles (640 km.), an elevation of 20 feet (6 m.) has occurred, in which there is no sign of warping. This uplift has laid bare a narrow marine shelf, overlooked by an old sea cliff—the most remarkable record of wave work in the province. Around the head of the Bay of Fundy, on the other hand, tree stumps buried deeply beneath the salt marsh deposits, indicate a recent subsidence of the coast. No satisfactory correlation of these data has yet been reached. At present although the coast generally is being rapidly cut away by the sea, it seems to be neither rising nor sinking.

Upland of northwestern New Brunswick.—From the head of Chaleur bay and the Gaspe peninsula southwestward, a wide belt of upland country stretches across the northwest corner of New Brunswick into Maine. In structure it is a part of the great Appalachian upland of northern New England. Its rocks are mainly calcareous slates and limestones of Silurian age. During one of the periods of long continued denudation, perhaps in the Tertiary, this district and the adjoining territory in Quebec was reduced to a lowland, while the district just east of it, the Central Highland of New Brunswick, remained standing because of its harder rock structure. The plateau-like altitude of the upland as we see it to-day was gained subsequently, when the peneplain, together with the adjoining highland was raised several hundred feet. Since then it has been very extensively dissected by streams. The hilltops of this upland range from 800 to 1,000 feet (240 to 300 m.) above the sea. A few residual mountains, as, for instance, Mars hill in Maine, five

miles west of Upper Kent station, rise several hundred feet above the peneplain.

Records of the Glacial period, as yet not extensively studied in this district, indicate that the continental ice passed southward and southeastward across it—whether from a centre north of the St. Lawrence or from a local centre on the Appalachian highland of southeastern Quebec cannot now be stated. During the closing stages of glaciation, the larger valleys, notably that of the St. John river, were heavily aggraded with outwash deposits, which ceased to accumulate as soon as the ice sheet had withdrawn from their basins, and have since been deeply re-excavated by the rivers which occupy them. In this work of intrenchment, the rivers have swung too and fro within limits set by the bed rock slopes on either hand, repeatedly striking ledges, from which they have retired, leaving step-like flights of terraces.

The Central Highland of New Brunswick.—Just east of the district last described, and occupying a large area in the north central part of New Brunswick, is a vast rough wilderness known as the Central highland. Its greater relief is due to the superior strength of the granites and gneisses which appear extensively on its surface. There is a rough accordance of plateau-like remnants at 1,700 feet (515 m.), which are overlooked by summits of rather subdued form that rise as high as 2,500 feet (760 m.). The hills and ridges trend northeast-southwest, following the trend of rock structure. Around the border of this highland is a belt of foot hills and ridges of moderate relief, developed on hard sandstones and slates. Apparently the highland is an imperfectly reduced portion of the great Cretaceous peneplain of New England, which, like the higher parts of the White mountains of New Hampshire and Mt. Ktaadn in Maine, retain subdued mountain form.

Lowlands of eastern New Brunswick and northwestern Nova Scotia.—The Carboniferous lowland of eastern New Brunswick in its structure and history, is simply an extension of the Cumberland lowland of Nova Scotia. Its area, however, is very much greater than that of the other, and its relief, in the more remote interior is stronger. Between Newcastle and Bathurst the highest point reached by the railway is Bartibog station, 520 feet (158·5 m.). In this district the valleys are deep and narrow, with banks

kept steep by lateral planation. The upland is noticeably uniform in height. West and southwest of Bathurst on the other hand, where stronger Ordovician and Silurian strata and large stocks of granite come to the surface, the upland is higher and rougher. The Tertiary peneplain *par excellence* is found along the coast of Gloucester county east of Bathurst. There the upland is exceedingly smooth and ow. The valleys which thoroughly indent it are broad and shallow, turning and twisting in graceful curves, and branching repeatedly in all directions. The dissection of this part of the peneplain is fully mature. Drowning appears to have taken place early in the Pleistocene; at least, it is clear that before the close of the Ice Age, while the interior of the province was still covered by the ice sheet, these valleys were more deeply submerged than now. Below the 150-foot (45 m.) level the coast is very generally covered with a sheet of residual sands overlying the decayed sandstones. Upon this loose material rests a few inches of wave-washed sediment and a scattering of subangular till pebbles and striated boulders. Clearly, the weathered surface of the peneplain here has escaped erosion from the continental ice sheet by remaining under water while pack ice or bergs, drifting along the shore, dropped glacial debris sparingly on its surface. Here is true glacial "drift" in the sense used by Sir Charles Lyell. The extent of this coastal submergence is obscurely marked by gravelly beaches which range from 150 feet (45 m.) at Newcastle to 195 feet (59·5 m.) at Bathurst.

The Upland of southern New Brunswick.—Bordering the Bay of Fundy coast of the province of New Brunswick, is another upland district—the Southern upland—similar in origin and in general form to the Central highland. Its average altitude, however, is lower, being approximately 1,000 feet (300 m.).

Rivers of New Brunswick.—The transverse course of the St. John river, from its head waters in the upland of northwestern New Brunswick across the Central highlands, the Carboniferous lowland and the Southern upland, to the Bay of Fundy shows an extraordinary disregard for structure and for recent topography. The deep intrenchment of the river through the highlands can hardly be explained in any other way than by supposing that it was impressed on the peneplain during the Cretaceous

period. The southeastward direction which the river in general maintains agrees with the southeastward slant of the upland itself, as extended from the 1,700-foot (515 m.) surface of the Central highland across the lowland interval, along the skyline of the 1,000-foot (300-m.) Southern upland, and further, over the Bay of Fundy and along the skyline of the 500-foot (150 m.) upland of Nova Scotia. Other rivers which drain the Central highland, as, for example, the Miramichi, heading in streams which trend parallel to the St. John, turn abruptly towards the northeast where they enter the area of Carboniferous rocks and run out to the gulf down the slope of the lowland. This is probably due to wholesale piracy in the Carboniferous area after the uplift of the Cretaceous peneplain. During the development of the lower Tertiary plain on this transverse belt of soft rocks, the southeastward flowing streams suffered from inroads of the rapidly growing headwaters of the lowland rivers; and the St. John alone remained intact. The broad, deep estuary of the Petitcodiac at the head of Shepody bay occupies perhaps the mouth of one of these master rivers of Cretaceous and of early Tertiary time, whose headwaters now drain out through the Miramichi.

The drowning of the mouths of these large rivers records a downward movement of the coast which affected the whole northern part of the continent. The fiord coast of Maine is a continuation of the ragged coast of the Southern upland. The exact date of the submergence is not known. There is no lack of evidence, however, to show that by the close of the Glacial period the coast had sunk to a level approximately 200 feet (60m.) below its present position.

Upland of Nova Scotia.—The greater part of the peninsula of Nova Scotia is underlain by a complex of ancient rocks. Most of the area exhibits the outcropping edges of a very thick series of slates, associated with a likewise extensive older group of quartzites. During the early Palæozoic these were folded and crumpled into structures so complex that very high mountains must have resulted. At the same time the base of the range was punctured and displaced by enormous masses of granite. Since this mountain building, the surface has been worn down to a plain of low relief. In place of peaks of Alpine form and height there are to-day subdued hills and ridges which range from

600 to 1,000 feet (180 to 300 m.) in altitude. The accordance of the summits of these hills, although not perfect, is so close, particularly in view of the mountain structures which are truncated by the gently undulating surface, that the plateau can be regarded as an ancient plain of subaerial denudation, similar to and contemporaneous with the upland of southern New Brunswick and the peneplain of southern New England. The surface of the upland slopes gently and steadily seaward, from northwest to southeast, as a result of the regional uplift which it has suffered since the period of base levelling.

The upland also presents the appearance of having been carved intaglio. Sunk beneath its surface are valleys too numerous to count. In the higher northern part of the peninsula,—for example, around Arisaig and Antigonish,—the valleys are deep and gorge-like. Farther south, where the plateau is lower, the valleys are shallower and are somewhat obscured by a filling of glacial drift. Here as in other parts of the Appalachian province, the dissection of the upwarped Cretaceous peneplain has been deep and sharp in the elevated interior and shallower and wider near the coast.

The Cobequid mountains, crossed by the Intercolonial railway about midway between Amherst and Truro, may be regarded as a connecting link between the upland of Nova Scotia and the upland of southern New Brunswick. Here, on an outlying mass of hard crystalline rocks, the surface of the Cretaceous peneplain has been preserved while the intervening sediments have been reduced to lower levels.

Cumberland and Colchester lowlands.—The areas occupied by the comparatively weak sediments of Carboniferous, Permian and Triassic age, more especially over the isthmus that ties Nova Scotia to New Brunswick around the head of the Bay of Fundy, are lowlands, half drowned by the sea. Following the uplift of the Cretaceous peneplain, denudation by the rejuvenated rivers, proceeding with far greater rapidity in these areas of non-resistant rocks, developed a secondary peneplain while the areas of harder structure both east and west were left standing as deeply dissected plateau masses. This lower, later peneplain of the Tertiary period extends northwestward along the shore of the gulf, over eastern New Brunswick and Prince Edward Island. Like the older peneplain, this lowland of the Tertiary

cycle has been upwarped and dissected. Nor does this complete its history; for subsequently to its dissection, probably during the Pleistocene, the lowland has subsided, letting the sea up over the lower portions and drowning the broad trunk valleys to form tidal "basins".

It is more than probable that other changes of level have taken place along the coast since the beginning of the Glacial period. The evidence of these later oscillations, however, have not yet been fully gathered and correlated. Extensive plains of stratified sand and clay which cover the lower 100 feet (30 m.) or so of the coast, more especially where rivers formerly entered the sea, appear to be marine or estuarine deposits formed during a period of greater submergence than the present. Wave carved cliffs and wave built beaches, however, if present, are too obscure to justify any statement as to the altitude of the upper limit of post-Glacial submergence. The extreme range of tide complicates the problem. More interesting still is the question of the modern stability or instability of the coast. The salt marshes at Sackville and Dorchester furnish suggestive material for study of this problem. At Fort Lawrence, near Amherst, a buried forest is exposed at low tide beneath 30 feet (9 m.) of marsh mud, and 8 feet (2·4 m.) below mean tide level. While this is indisputable evidence of coastal subsidence, it may date from early post-Glacial time, and proves nothing about modern stability or instability.

Cape Breton.—Separated as it is from Nova Scotia by hardly a mile of water, at the Straits of Canso, the Island of Cape Breton is a part of the province just described. Both the Cretaceous upland and the Tertiary lowland extend over from the peninsula; but the harder and the softer rock structures on which these two physiographic facets are respectively developed are so irregularly distributed over the island that the upland and lowland districts interrupt each other very strongly.

Two areas particularly in which metamorphosed strata and granitic stocks prevail are upland districts; the wide northern arm of the island including most of Victoria county, and the southeastern border of the island east of Bras d'Or lake and south of Sydney. The central portion of the island, on the other hand, from the Sydney district across Bras d'Or lake and northwestward to the gulf, in which soft Carboniferous sediments prevail, is an

undulating lowland. The central part of this dissected lowland, like the coast in Cumberland and Colchester counties in Nova Scotia, has been drowned by depression beneath the sea, forming the Bras d'Or lakes. The largest lake is separated from the ocean at its southern end by a narrow strip of land only a mile wide. The long arms of these lakes and of the peninsulas which separate them are developed along the strike, respectively, of the weaker Palæozoic sedimentaries and the more resistant granitic and metamorphic belts. Great Bras d'Or has a depth of 350 feet (106 m.); Little Bras d'Or lake, 700 feet (215 m.). Not all this depth is necessarily due to coastal subsidence since the late Tertiary dissection; for the island has been glaciated, and the amount of differential erosion below sealevel may have been very considerable.

ANNOTATED GUIDE.

MONTREAL TO LÉVIS.

(G. A. YOUNG.)

Miles and Kilometres.

0. m.
0 km.

Montreal. Leaving Montreal, the Intercolonial railway (from Montreal to Ste. Rosalie, the Intercolonial runs over the Grand Trunk railway) crosses the St. Lawrence river and follows a general northeasterly course through a district underlain by Palæozoic strata, mainly of Ordovician age. The district traversed is a portion of the St. Lawrence lowland or plain which extends far westward up the valley of the St. Lawrence and the Great Lakes. The northwestern portion of the plain is underlain by an apparently conformable succession of Ordovician strata dipping at very low angles to the southeast. The oldest measures are displayed along the borders of the great Pre-Cambrian area to the northwest, while the youngest beds outcrop towards the centre of the plain. Though disconformities presumably exist, the strata appear to afford a complete section of the Ordovician system.

Miles and Kilometres.

The southeastern portion of the plain is occupied by closely folded and faulted measures of Ordovician and, possibly, Cambrian age. These disturbed measures are lithologically and faunally unlike the flat-lying, in part, at least, contemporaneous strata of the northwestern portion of the region. They belong to the geological province which includes the elevated bordering uplands on the southeast underlain by strata ranging in age from Pre-Cambrian to Devonian and which are accompanied by igneous rocks of both volcanic and plutonic types.

The boundary between the gently dipping Ordovician on the northwest and the much disturbed, in part metamorphosed, strata on the southeast, though it traverses the length of the lowlands, is not marked at the surface by any topographical feature. The level, plain-like surface extends uninterruptedly across the boundary which is formed by a zone of faulting, known as the St. Lawrence and Champlain fault. This zone of faulting extends in a nearly straight course northeast from the foot of Lake Champlain to the St. Lawrence river a few miles above Quebec. From there it continues northeastward down the channel of the St. Lawrence. This fault or zone of faulting, first recognized by Sir W. E. Logan, has a length of,
162.8 m. presumably, about 900 miles (1450 km.).
262 km. **Lévis.** (Opposite Quebec city).

QUEBEC AND VICINITY.

(Percy E. Raymond.)

INTRODUCTION.

The beetling cliffs which make Quebec the "Gibraltar of America" have been a puzzle to geologists since the earliest days of the science in America. The "Quebec

*See Map,-Quebec and Vicimty.

group," involved, as it became, with the "Taconic" controversy and the "Theory of colonies," was for many years the subject of hot and world-wide discussion. Such noted men as Lyell, Bigsby, Logan, Billings, Marcou, Selwyn, and Hunt have repeatedly clambered over these rocks, and given to the world the most diverse views as to their age and relative positions. Barrande took a part in the wordy war, and Lapworth furnished one of the most important clues for unravelling the tangle. Although there is still much to be learned, the discovery of fossils and a closer study of the structure have elucidated the main features of the region. To this more recent work, Walcott, Ells, Weston, and Ami have been the main contributors.

The City of Quebec lies principally upon a narrow and high promontory on the north side of the St. Lawrence. To the north of the city is a broad valley, now occupied by the St. Charles river, but which was, at no very ancient date, the main valley of the St. Lawrence. Quebec city thus occupies the eastern point of a long narrow ridge, the western edge of which is at Cape Rouge, 8 miles above the city. To the south of this ridge is the narrow gorge now occupied by the St. Lawrence, and to the north, the broad valley occupied in part by the St. Charles. North and east of the latter valley is the Pre-Cambrian highland, bordered by a narrow belt of Ordovician sediments. South of the St. Lawrence rise the steep cliffs of Lévis. The sediments north of the St. Charles rest upon the Pre-Cambrian, and the oldest are of Trenton (Middle Ordovician) and the newest of Lorraine age (Upper Ordovician). The promontory on which Quebec city is built consists of shale and limestone of Middle Trenton age and the strata on the south side of the river are of Beekmantown age (Lower Ordovician).

The prevailing strike of all the beds is northeast-southwest, magnetic, and the strata are thrown into tightly folded, overturned anticlines and synclines with steep dips to the southeast. There are three major faults approximately parallel to the strike, two of them thrust faults with a heavy throw to the northwest, and one normal fault with a drop to the southeast. The first of the thrust faults occupies the bed of the St. Lawrence

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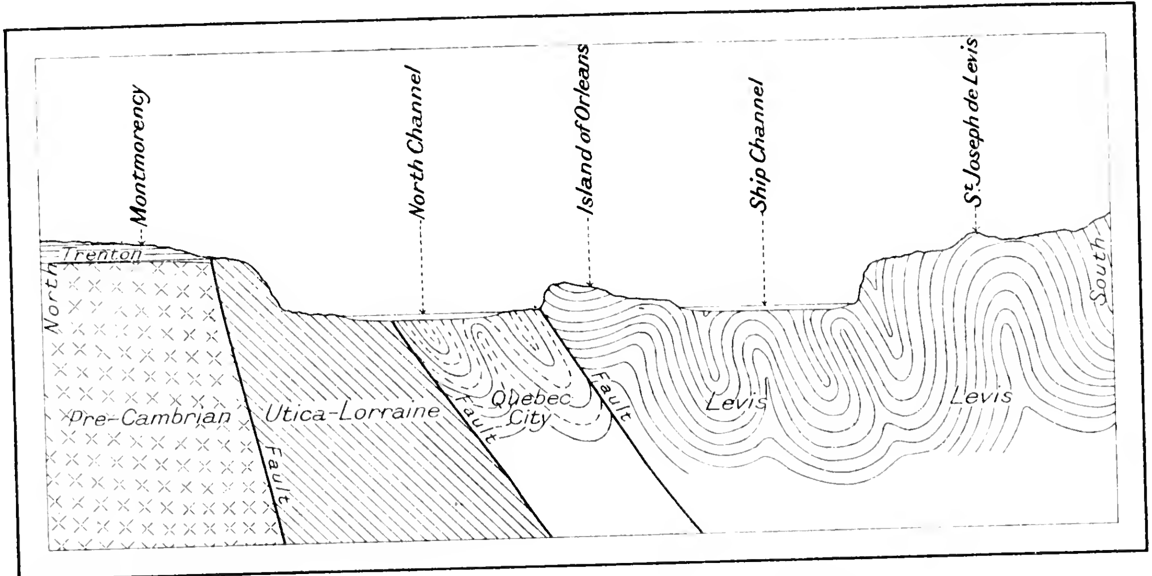

Geological Survey, Canada

Generalized section across St. Lawrence Valley

between Quebec and Lévis, but is seen along the northern side of Orleans island, where the Lévis formation is thrust upon the Quebec city formation. The second fault passes from above Cape Rouge on the St. Lawrence along the northern side of the ridge on which the city is situated and thence along the valley of the St. Charles into the St. Lawrence, where it passes between Orleans island and the north shore at Montmorency. By this fault the Quebec City formation is thrust over the Sillery and Lorraine. The third fault is well shown at Montmorency, where, by a drop of about 600 feet (180 m.) the Lorraine is brought down to abut against the Pre-Cambrian.

The main structure and the faults are shown in the accompanying generalized section across the valley.

In the absence of any detailed knowledge, the amount of lateral movement involved in the thrusts can only be conjectured. It must be very great however, for the Sillery, Lévis and Quebec City formations do not belong to the same province of deposition as the Trenton, Utica, and Lorraine. In the region north of the St. Lawrence the Trenton rests upon the Pre-Cambrian with sponges and corals adhering to the gneiss in the position in which they grew, thus showing that the contact is not due to a fault. Yet, only a mile away, on the Island of Orleans, is a great thickness of older (Lower Ordovician) rocks. Logan explained this by assuming a very great steepness for the shore line here, so that the gneiss of Montmorency was not submerged till Trenton time, but now that we know that both the Quebec City formation and the limestone at Montmorency are of Trenton age, though with hardly a fossil in common, it becomes impossible to accept this explanation. In New York State, the strata containing the same fauna as the Quebec City rocks, lie nearly 50 miles (80 km.) east of the nearest outcrop of strata containing the typical Trenton fauna, but the thrust need not necessarily have been so much as that.

The following formations, amongst others, occur in the vicinity of Lévis, Quebec, and Montmorency.

		At Quebec and Lévis.	*At Montmorency.*
Ordovician	Upper	.	Lorraine.
			Utica.
	Middle	Quebec City.	Trenton.
	Lower	Lévis.	
		Sillery.	

LORRAINE (FRANKFORT) FORMATION.

The Lorraine in this vicinity, is a fine, soft, grey shale, with thin layers (1 to 3 inches in thickness) of sandstone. There are occasional thicker layers of sand or limestone conglomerate. The thickness is at least 700 feet (215 m.), with the top not seen. Fossils, other than a single species of graptolite, *Diplograptus pristis*, are not common, but a few species, *Triarthrus becki*, *Cryptolithus tessellatus*, *Plectambonites sericeus* and *Dalmanella testudinaria*, have been found.

UTICA FORMATION.

The Utica is a much darker and less micaceous shale than the Lorraine, and contains, besides *Triarthrus becki* and *Leptobolus insignis*, a considerable variety of graptolites, *Climacograptus typicalis* and *Climacograptus bicornis* being the more common. At the base is a small thickness of impure, blocky limestone containing the same fauna, with the addition of a few survivors from the Trenton. The total thickness of the Utica is about 200 feet (60 m.).

TRENTON FORMATION.

The Trenton consists of thin-bedded, dark blue limestone with shaly partings. It is extensively quarried, and used for all purposes, from building stone to road metal.

The Trenton here may be divided, on the basis of fossils, into four zones, all of which can be traced from Quebec to central New York and some of which are

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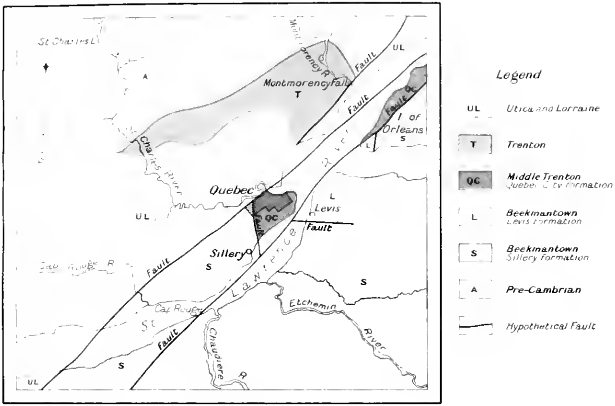

Geological Survey, Canada

Quebec and Vicinity

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recognizable as far west as Minnesota. The fossils characteristic of the upper zone are *Prasopora simulatrix* and *Dinorthis meedsi*. The principal fossils of the next lower zone are, *Cryptolithus tessellatus* and *Triplecia nuclea*, while in the zone below is the nautiloid, *Trocholites canadensis*. Finally, at the base, are a few feet of strata with *Parastrophia hemiplicata*. The first fauna occupies the upper four-fifths of the formation, and the last three the lower fifth. The total thickness is about 500 feet (150 m.).

QUEBEC CITY FORMATION.

The Quebec City formation consists of hard, fine-grained limestone, very dark shale, and thick and thin beds of limestone conglomerate. The shales are frequently more or less altered and show secondary cleavage, but sometimes contain rather well preserved graptolites, among them such forms as *Corynoides calycularis*, *Climacograptus bicornis*, and *Cryptograptus tricornis*, fossils which are indicative of a mid-Trenton age. A few fossils other than graptolites have been found, but they are small shells, of no value in correlation.

The pebbles in the conglomerate are quite fossiliferous and contain such fossils as *Plectambonites pisum*, *Tretaspis diademata*, *Lonchodomas hastatus*, and *Nidulites*, all unknown in the typical Trenton. Strata containing these fossils are now known to occur in eastern Pennsylvania and Virginia, where they are found in that part of the Ordovician section which elsewhere is usually occupied by the Black River and Lower Trenton. The thickness of the Quebec City formation is unknown.

LÉVIS FORMATION.

The Lévis formation consists mostly of hard, grey, green, and red shale, thin-bedded hard, blue and light grey limestone, and thick and thin beds of limestone conglomerate. Neither the top nor bottom of the formation is known. About 1,000 feet (300 m.) of strata are exposed in the vicinity of Lévis. The shales contain a graptolite fauna, the more prominent species being *Phyllograptus typus* and *Tetragraptus quadribranchiatus*. The limestones contain *Shumardia granulosa*, *Phyllograptus*,

and *Dictyonema*. The Lévis is thus to be correlated with similar deposits low in the Ordovician of Europe.

Very fossiliferous pebbles have been found in the conglomerates in the Lévis, and the fossils show them to be derived from strata of three geological ages. The pebbles are: 1st, Lower Cambrian limestone with *Olenellus*, *Salterella*, etc.; 2nd, Upper Cambrian or Lower Ordovician, ("Tremadoc" or "Ozarkian") with *Symphysurus*, *Dikelocephalus*, etc.; 3rd, Beekmantown, with *Lloydia saffordi*, *Camarella calcifera*, and a great variety of brachiopods and cephalopods. Besides the limestone pebbles there are many of igneous rocks and quartzites, but they do not form nearly so large a proportion of the conglomerate as do those composed of limestone. The conglomerates also contain pebbles of the red and green shale and sandstone of the Sillery, thus proving that the Sillery is older than the Lévis, while the presence of Beekmantown fossils in both pebbles and matrix of the conglomerates shows that the Lévis is of the same age as the Beekmantown at Philipsburg, Quebec. There are no outcrops of limestone containing the *Olenellus* fauna nearer than Labrador, 500 miles (800 km.) northeast of Lévis; the nearest outcrop of limestone containing the *Dikelocephalus* fauna is at Whitehall, N.Y., 250 miles (400 km.) southwest; and the nearest outcrop of fossiliferous Beekmantown is at Bedford, Que., 150 miles (240 km.) southwest of Lévis. Yet the vast numbers and often large size of the pebbles in the conglomerates indicate that the older limestones outcropped near the basin where the Lévis shales were formed, and it seems very probable that such beds now exist somewhere to the southeast of Lévis, entirely buried by the shales which have been thrust over them.

SILLERY FORMATION.

The Sillery is the oldest sedimentary formation now seen in the district, and very little is known of it. It consists of red and green shales, and lenticular masses of red and green sandstone. Like the Lévis it is thrown into tightly compressed over-turned folds, and contains so few hard beds that it is practically impossible to work out its detailed structure. With the exception of the little inarticulate brachiopods, *Linarssonia pretiosa*, fossils are almost entirely lacking. The few that have been found, species

of *Phyllograptus* and other graptolites, indicate a close similarity to the fauna of the Lévis. The Sillery also contains layers of limestone conglomerate, but the pebbles differ from the conglomerates in the Lévis in containing Lower Cambrian fossils almost exclusively, although an occasional specimen has been found which indicates the *Dikelocephalus* fauna. The thickness of the Sillery is unknown.

HISTORICAL NOTE.

The earliest account of the rocks in the vicinity of Quebec and Point Lévis is in a paper published in 1827 by Dr. J. Bigsby [**1**]. Bigsby divided the rocks into three series, the gneiss, shell-bearing limestone, and a slaty series with conglomerate, and decided that the sedimentaries belonged to the Carboniferous series. Logan [**2**] in 1843, thought that the strata of Lévis were below the limestone north of the St. Lawrence, but finally adopted the view that they were above, and thus the equivalents of the Hudson river and Lorraine of New York State. In 1855, Logan [**3**] believed the Sillery to be the youngest of the formations present, and correlated it with the Upper Silurian "Shawangunk or Oneida conglomerate" of New York.

In 1857, James Hall [**4**] reported on the graptolites of Point Lévis, and referred the shales containing them to the Hudson River group. Billings then took up the study of the fossils found in the conglomerates at Point Lévis, and Logan [**5**] announced in 1860 that Billings had identified these fossils as of Chazy and Calciferous (Beekmantown) age, and that, therefore, the Lévis strata belong at the base of the Lower Silurian. In this paper the term Quebec group was first used and the course of the Champlain-St. Lawrence fault outlined. Marcou, [**6**] in 1862, took exception to the views of Logan, and correlated the strata at Point Lévis with the Georgia shales (Lower Cambrian) of Vermont. Marcou explained the appearance of younger fossils in the conglomerates on the basis of Barrande's doctrine of colonies.

Billings, [**7**] replying to Marcou in 1863, paralleled the strata of the fossiliferous part of the Quebec group with those of the Llandeilo of England and Australia, and the Calciferous and Chazy of America.

In the Geology of Canada, 1863, Logan [**8**] described the Quebec group in great detail, tracing it from the well known exposures at Point Lévis both east and southwest, where it was supposed to have been altered into a complex series of crystallines. He still believed the Sillery to be above the Lévis, "provided the series was not inverted." He gives a map showing the structure at Point Lévis, and divides the Lévis into 17 zones, with a total thickness of 5,025 feet (1530 m.). The thickness of the Sillery was estimated at 2,000 feet (600 m.).

A comparison of the sections in Canada and Newfoundland led Billings [**9**] in 1865 to the opinion that the shales at Point Lévis were at least 2,000 feet (600 m.) above the Calciferous (Beekmantown).

Lapworth, [**10**] in 1886, identified a number of graptolites made by T. C. Weston, and correlated the fauna found at Point Lévis with that found in the Arenig of England. He also studied the graptolite fauna which had been collected in the City of Quebec, and stated that their age was probably Black River or Lower Trenton. The above correlations have since that time been universally adopted.

Ells, [**11**] in 1888, gave an excellent summary of all work up to that time, a detailed description of the various formations in this region, and many new lists of fossils, the latter determined by H. M. Ami.

A POSSIBLE EXPLANATION OF THE GEOLOGICAL STRUCTURE.

The prevailing strike of all the sedimentary rocks in this area being NE–SW, and the dips generally to the SE, it was at first supposed that the strata formed a regular ascending series from the gneiss at Montmorency to the supposed Upper Silurian red shales of the Sillery south of the St. Lawrence. The discovery of fossils, however, showed this view to be incorrect, and each subsequent collection of fossils has shown the structure to be more complicated than it had previously appeared.

From our present knowledge of the distribution of the faunas it would seem that at Montmorency we are near the southern margin of a great area of Trenton rocks which once extended far over the Laurentian highlands to the north. Infaulted remnants of such an expanse of limestone occur at Lake St. John, 200 miles (320 km.) northeast of Quebec, and at various other places north of the St. Lawrence. This limestone does not seem to have extended to any great distance south of the St. Lawrence, and during Trenton time there was probably a barrier here, to the south of which was a sea containing the Altantic facies of the Trenton fauna (Quebec City formation). South of this barrier Lower and Upper Cambrian, Sillery and Lévis strata had also been deposited but after Trenton time the barrier may have been submerged, so that Lorraine and Richmond shales may have been deposited over both the Trenton and the Quebec City formations.

It is generally conceded that the pressure which accompanied the Appalachian mountain building was exerted largely from the ocean side, and hence all overturning and thrusting at Quebec would be expected to be, as it is, from the southeast. It would seem that when the force was exerted against the great mass of Cambrian and Lower Ordovician strata which had accumulated south of the St. Lawrence, the Lower and Upper Cambrian limestones remained anchored, while the soft Sillery shales allowed the development of a thrust plane within their mass, so that a great thickness of Sillery, Lévis, and Quebec City rocks was pushed toward the northeast from their original position. The drag at the bottom of such a thrust-block would tend to delay the anterior end, thus swelling the strata into an anticline. The front of this block, on reaching the scarps of the normal faults which had developed in this region would be stopped, and the anticline completely overturned and secondary thrust planes developed, so that the lower strata in the block would be thrust over the higher ones. If the greater part of such an overturned and fractured anticline were eroded away, the resulting arrangement of the formations would be such as is shown on the accompanying geological map of the Quebec area. This would account for the fact that the oldest strata, the Sillery, really appear highest in the section, and also for the non appearance of the Cambrian strata from which the boulders in the Sillery and Lévis were derived. It

would also explain the fact that the Sillery and Lévis are much more crumpled and folded than the Quebec City, the latter formation being higher in the block, and so less exposed to friction during transport. It would still further account for the fact that the Quebec City and Lévis are exposed only in narrow bands close to the river, whereas the Sillery forms the greater areas to the south.

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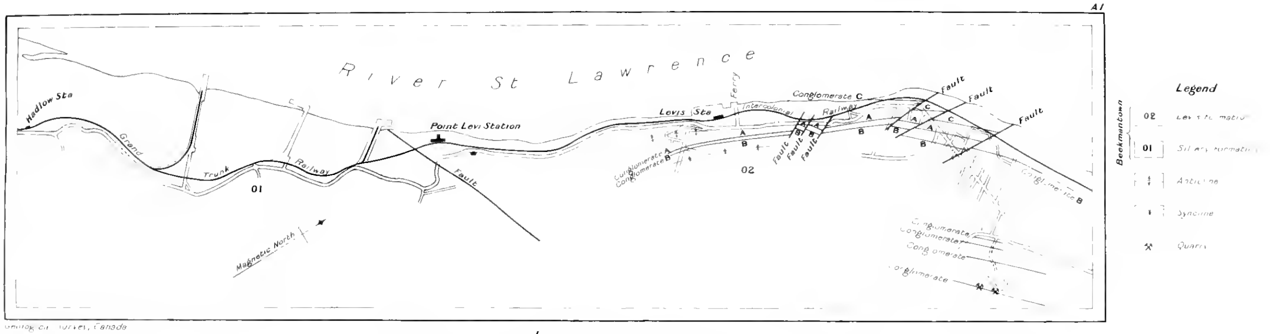
The graptolites at Point Lévis were described in the following memoir:—

Hall, James.—Geological Survey of Canada. Figures and Descriptions of Canadian Organic Remains, Decade II. Graptolites of the Quebec Group. 1865.



Levis

Feet: 1000 0 1000 2000 3000 4000 5000

Metres: 100 0 500 1000 1500

(Scale of map is approximate)

DETAILED DESCRIPTION

LÉVIS: THE SHALES AND CONGLOMERATES OF THE LÉVIS AND SILLERY FORMATIONS.*

The high bluff on the south side of Main street, Lévis, which runs in a southwest direction from the neighbourhood of the Intercolonial Railway station, is composed of shale, limestone and limestone conglomerate of the Lévis formation. The Lévis formation continues until the turn at Point Lévi is reached, and beyond that point one sees only red and green shale and sandstone of the Sillery.

Along the roadside at Hadlow, there is a cutting in one of the sandstone beds of the Sillery. At this point the sandstone is so folded upon itself as to give the impression of considerable thickness. A few rods back, however, in a ravine which cuts across the cliff, the same sandstone is seen to have a thickness of only about 10 feet (3 m.).

A few rods farther to the southeast, just beyond the ravine, the red and green shales of the Sillery formation are exposed.

From this general neighbourhood an uninterrupted view is obtainable of the bluff on the northern or Quebec side of the river. The structures and formations displayed in this bluff are of great geological interest. The church on the bluff up the river and to the left is at Sillery, the town which has given name to the formation. The red colour of the bluffs at Sillery point can be seen, and the red shale bluffs extend down to the wooded cove which is almost opposite Hadlow. This wooded cove was the landing place of Wolfe's army, and bears his name. There is a fault at Wolfe's cove, and the cliffs from that point to the citadel are composed of hard shales and limestone of the Quebec City formation. The prominent building across the river, on top of the bluff, is the city gaol. To the left of the gaol are the Plains of Abraham, the battle field of 1759. About half way between the goal and the Citadel is the drill hall in the Cove Fields, and it was the excavation for the foundations of the drill hall which furnished the well-preserved graptolites from which the Middle Trenton age of the Quebec City formation was determined. The prominent cliff in line with this building

*See Map--Lévis.

is Cape Diamond, and the rocks of the Cape and east of it are much more massive than those to the west. They are almost devoid of fossils.

At the exposures of the Sillery, on the Lévis side, just northeast of the ravine at Hadlow, the lower part of the cliff is seen to be made up of a bright red shale with green spots and streaks, while the upper part of the bluff is composed of green shale. In fragments of both red and green shale on the talus at the foot of the cliff, specimens of the only common Sillery fossil, *Linarssonia pretiosa*, (Billings) may be found.

From this place as far northeast as Point Lévi red shale and thin sandy beds form the cliff on the southeast.

At Point Lévi, it may be noticed that the red and green shales extend as far as a small ravine close to the street car switch, and that harder grey shales are then encountered. Around the corner, behind the last house of the row to the right are grey shales with occasional bands of red, but beyond this point there is nothing but hard grey shale and limestone. The first impression received is that the Sillery lies above the grey shales, which belong to the Lévis, and that there is a gradation between the two indicated by the alternation of red and grey beds. A closer study of the cliffs, and the distribution of the beds on the flat at the top of the cliff, shows that there is here in reality a marked change along the strike, and that there must be a fault separating the Lévis from the Sillery. There is, in fact, a small slip to be seen back of the easternmost house, and there is evidence of disturbance in the little ravine already referred to.

From Point Lévi to the foot of Davidson street, many folds in the hard limestone are visible in the cliff along Main street.

On the eastern side of Davidson street some distance above Main street and just below the bend in the road, a cutting has revealed the arch of an overturned anticline. The strata here are thin-bedded limestone and shale. The limestone contains *Dictyonema*, *Shumardia* and other fossils and is locally known as the Shumardia limestone. The overturned condition of the strata is well shown here, the dip being uniformly southeast at an angle of 50° except for a short distance at the centre of the arch. The squeezing out of certain beds, particularly a thick shale, is also shown here.

Up the hill, thick beds of limestone are visible back of the little corner house, and between the beds of limestone are layers of shale with *Tetragraptus* and other graptolites.

Continuing up Davidson street to Côte du Passage, across that street and a short distance up a lane, one comes upon a heavy bed of limestone conglomerate with red and green shales on either side. As practically all the measures between this conglomerate and the centre

Anticline in Shumardia limestone. Davidson street, Lévis.

of the anticline are exposed, and as there is no change of dip, it is evident that the conglomerate is above the Shumardia limestone. About 175 feet (53·3 m.) of shale and limestone intervene between the two.

If this conglomerate which may be called conglomerate A, is followed eastward to the next street, it will be seen a short distance up the road from the top of the ruined elevator, and at the corner of the street above is a poor exposure of another conglomerate, marked B on the accompanying map. Descending the hill from Côte du Passage the same shales and limestones noted above the anticline are again observable in rock cuts. The centre of the

anticline lies at the bend in the road and the beds encountered below are a repetition of those above. The thick beds of grey limestone at the foot of the elevator should be noted and compared with those exposed in the cutting at the top of the hill.

From the foot of Côte du passage and Davidson street, northeastward along Main street, two bands of the thin-bedded Shumardia limestone can be seen extending along the face of the bluff to the wooden steps. Here the limestones disappear below the street level, and the axis of the anticline passes to the river side of the road. Between the next two buildings on the southeast, 500 feet (150 m.) east of the steps a fault brings conglomerate A down nearly to the bottom of the cliff, and conglomerate B to the top of the bluff face.

The B conglomerate here is mostly thin-bedded limestone, with a little conglomerate at top and bottom. At the small point just beyond these two houses another fault brings conglomerate A down to the foot of the cliff, and B down against A. Immediately on the point are two other minor slips.

Beyond this point, are the best exposures in the vicinity of Lévis. Conglomerate A, which is 15 feet (4·5 m.) thick at the point where the faults occur, can be traced past the lime kiln at the foot of the bluff, up into the bluff face, where it dwindles to a mere two-foot bed. Above it is a conspicuous layer of thin-bedded limestone, and still higher the thin-bedded limestone of conglomerate B. The latter bed is here quite fossiliferous and contains *Phyllograptus anna*, *Dictyonema*, *Shumardia granulosa* *Lingula quebecensis* and other fossils. In the middle of the cliff, below conglomerate A. is more thin-bedded limestone and the fossils prove it to be the Shumardia limestone, here freed from the effect of the anticline and without the thick beds of grey limestone that are above it on Davidson street. Ten feet below this limestone is a hard grey shale with *Dawsonia*, *Phyllograptus*, *Dichograptus*, and brachiopods.

By following the first street leading southward from Main street at the top of the hill, conglomerate B may be seen in more detail. At first sight this appears to be conglomerate A, but by following it along the surface, with almost every foot exposed, it is seen to run into a thin-bedded limestone at the top of the bluff. Returning

to the cutting on the road, conglomerate A will be seen in place below conglomerate B. The cutting on this road gives an excellent opportunity to study the conglomerate in detail. Many of the pebbles are large, sometimes more than a foot in diameter, usually more or less rectangular and not well rounded. The interstices between the larger pebbles, are filled with smaller pebbles, and there is very little paste. Most of the pebbles are of limestone, and many of them are fossiliferous. The fossils obtained here were chiefly of Beekmantown age. Some of the pebbles are themselves derived from a conglomerate, and others are composed of an oolitic limestone. Besides the limestone, pebbles of gneiss, quartzite, sandstone, and shale may be seen in this exposure.

LÉVIS TO MONTMORENCY FALLS.

An excellent view of Quebec may be had from the ferry while crossing from Lévis to Quebec. On the highest point is the Citadel, while about half way down the cliff is the Dufferin terrace and the Chateau Frontenac. The rocks which form the cliff are limestones and hard shales of the Quebec City formation (Middle Trenton).

After leaving the Quebec Ry. Light and Power Co. railway station, the St. Charles river is soon crossed by the electric tramway and the route proceeds along the low land near the shore until Beauport is reached.

At Beauport (2.8 miles, or 4.5 km.) a quarry in the Trenton limestone shows the strata to be thin-bedded, pure, blue-black limestone with thin shaly partings belonging to the middle division of the Trenton. Immediately beyond this quarry the train leaves the main line of the railroad and begins to mount the terrace. On this rather steep slope a cut has been made, exposing the Utica shale. This shale has a steep dip toward the river, whereas the Trenton strata in the quarry are horizontal. A fault which will be observed at Montmorency, passes between this cut and the quarry. Reaching the edge of the terrace, the railroad crosses the sloping top until it approaches the Beauport-Montmorency highway, which it parallels for the remainder of the distance. Numerous small quarries and lime kilns to the north of the railroad, show the presence of the Trenton limestone along the highway, the railroad itself remains upon the Utica and

Lorraine shales up to a point within a few rods of Kent House at Montmorency Falls. The highway is lined on both sides with the quaint houses of the French Canadians whose long, narrow farms extend to the river on one side and to the Laurentian hills on the other.

MONTMORENCY FALLS: (A) CREST OF FALLS, WESTERN SIDE.*

From this point one gets a good general view of the locality. The crest of the fall is 274 feet (83.5 m.) above sea level ,and the look-out point, on top of the building by the dam, is about 320 feet (97.5 m.)— A.T. In the bed of the river is Pre-Cambrian gneiss, and across the stream, the Trenton limestone is seen resting unconformably upon the gneiss, but with a dip conforming to the slope of the surface of the older rock. Below the falls is a great thickness (700 feet or 215 m.) of thin-bedded, micaceous shale of Lower Lorraine (Frankfort) age, and beneath it, 200 feet (60 m.) of black Utica shale. These shales instead of being nearly horizontal like the limestones above the falls, dip to the southeast at an angle of about 40°. The face of the fall is on a fault plane, and the top of the Trenton, at the base of the fall, is 270 feet (82.3 m.) below the base of the Trenton at the top of the fall, thus indicating a drop to the south of about 600 feet(180 m.) All along the western bank of the stream may be seen the thin-bedded Trenton limestone, which is quite fossiliferous, both near the look-out and at the western end of the road bridge above. The fauna is that of the *Trinucleus* zone, in the lower part of the Trenton.

Across the north channel of the St. Lawrence lies the Island of Orleans, and the low area on the nearer side of that island is composed of graptolite-bearing strata of the Quebec City formation, having about the same strike and dip as the Lorraine on this side of the river, thus implying the existence of a thrust in the bed of the St. Lawrence.

MONTMORENCY FALLS: (B) CREST OF FALLS, EASTERN SIDE.

While crossing the bridge above the falls, the ridges of gneiss on the eastern side of the river, both above and below the bridge should be noted. These ridges show the

*See Map :—Montmorency Falls.

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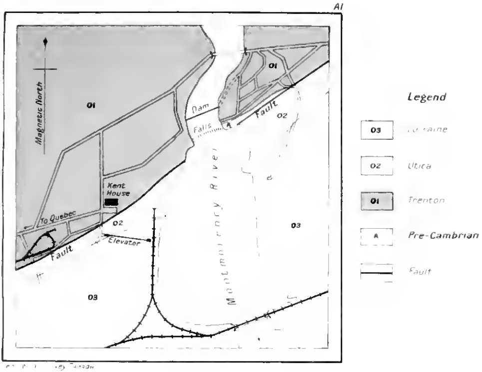


Montmorency Falls

Feet

Metre

100 200 300

(Scale of map approximate)

uneven character of the pre-Trenton surface. At the eastern end of the bridge, a path leads to the exposure on the bank of the river immediately below the concrete dam and just above the crest of the falls. Here the erosion of the rocks have revealed the bottom of the Trenton sea, and one may observe the Solenoporas growing on the sea floor, the calcareous mud filling hollows and cracks in the gneiss, and occasional boulders of the gneiss imbedded in the lower layers of the limestone. It will also be noted that the dip of the strata conforms to the irregularities in the sea floor, and that, while the unconformity here represents all of Cambrian and early Ordovician time, the basal conglomerate is insignificant in amount, indicating that this point was some distance off shore.

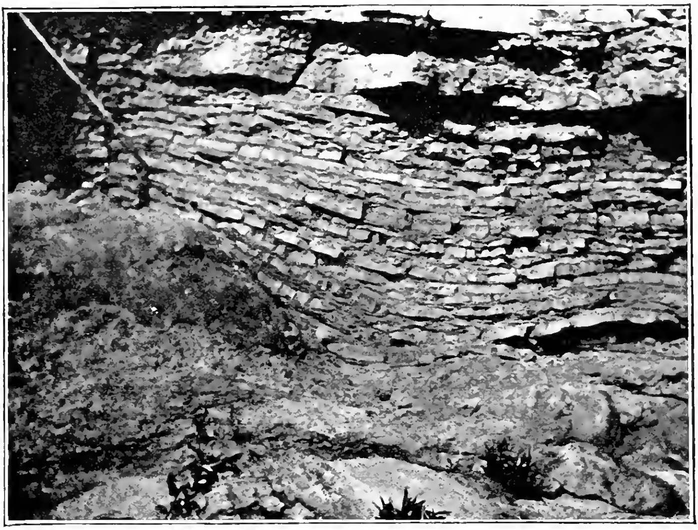
These beds are the oldest at this particular point; at the foot of a dam about one-half mile up the stream somewhat older beds outcrop which contain the oldest Trenton faunules, namely those with *Trocholites canadensis* and *Parastrophia hemiplicata*. All of the beds are newer than the Black River. On the weathered surfaces just above this exposure fossils are quite common, *Trinucleus concentricus* and *Eheirocrinus logani* (plates only) being most abundant.

From the crest of the falls on the eastern side of the river it is possible to continue down along the top of this bank, and near the point of the bluff facing the St. Lawrence, fossiliferous gravels of the Champlain period will be found with *Mya truncata*, *Saxicava*, *Macoma*, barnacles, and other fossils. Then, descending the dip slope to near the railroad tracks, one may find specimens of *Triarthrus becki* and graptolites in the Lorraine shales.

MONTMORENCY FALLS: (C) BASE OF FALLS

While descending on the elevator to the basin below the falls the Lorraine shales on both sides of the river may be seen. Proceeding up stream toward the falls, Lorraine-Utica shales are seen in the bed of the stream. Near the base of the falls, the fault-contact between the Utica and the gneiss is crossed. From this point there is an excellent view of the Pre-Cambrian gneiss along the fault plane, and in the direction of Kent House, the horizontal beds of the Trenton may be seen resting on the gneiss. A short distance up the bank on this side a crushed zone within

the Pre-Cambrian rocks indicates a movement parallel to the general fault but the horizontal limestone above crosses this fault plane without interruption, thus showing that it is of pre-Trenton age.



Contact of Trenton and Pre-Cambrian, top of Montmorency Falls.

Across the stream a small gully heading to the east has the gneiss for its northern wall, and at the bottom are a few layers of Upper Trenton limestone, followed by more limestone with *Triarthrus becki* and graptolites. The greater part of the southern wall of the gully however, is shale, and the contact of the Utica and the Lorraine may readily be seen, the Utica shale being much the darker of the two. The contact is a very irregular one, but this irregularity probably does not indicate an uncomformity, but rather that the effect of the fault has been to cause the Lorraine to slip somewhat upon the Utica. The point of rock which is so constantly bathed by the spray is Utica shale, and graptolites, chiefly *Climacograptus bicornis* and *Climacograptus typicalis* are quite plentiful on the side toward the falls. The Lorraine shales are not, in general, very fossiliferous, but certain layers contain a quatity of graptolites and incomplete specimens of *Triarthrus becki*.

SPECIAL POINTS OF INTEREST: QUEBEC CITY.

1. Sous le Cap and Champlain Streets.

Sous le Cap is an exceedingly narrow and not very pleasant street or alley under the cliff and is constantly shown visitors as the "narrowest street on the American continent," or the "narrowest street in the world." Passing close to the cliff it affords an occasional glimpse, on the north, of the shales and limestones of the Quebec city formation. Sous le Cap ends at St. Jacques street, from here, after turning into Sault au Matelot and continuing to Côte de la Montagne, one should turn up the hill and stop a few moments to examine the faulted and crushed conglomerate in the face of the bluff. The pebbles here are quite fossiliferous and contain the Lower Trenton fauna with *Nidulites, Ampyx, Tetraspis* and other fossils of the Atlantic facies.

Faulting has in large part been responsible for the structure shown in this cliff face, and the first impression conveyed is that this is not a conglomerate, but that the pebbles are due to the disruption of regular layers. After a comparison of this outcrop with others about the city however, it is believed that this is really a conglomerate torn up and softened by the crushing which has taken place in the faulting.

By retraversing Côte de la Montagne and turning into Notre Dame street, one passes the church of Notre Dame des Victoires, built in 1668. At the second corner, by turning into the Cul de Sac, the headquarters during the French regime of the rich pawnbrokers, one reaches Champlain street. Coming out of the Cul de Sac, the vacant space on the left is the old Champlain market. Beyond the Champlain market on the north, above the road, the nearly vertical limestone of the Quebec City formation is seen surmounted by the Dufferin terrace. At the further end of the terrace traces may still be seen of the great landslide of 1881. The strata here have a steep dip into the cliff. The upper ends of the beds formerly overhung the road, but finally they gave way and crashed down into the houses lining the road beneath, killing many people.

Beyond this point the nearly vertical strata, limestone and shale, form a great cliff along the north side of the road. The shale has in places a secondary cleavage.

Although extensive search has been made for fossils along this bluff, the work of various collectors for many years has been rewarded by only one or two badly preserved graptolites.

A tablet on the face of the cliff marks the spot where in an engagement on the last day of the year 1775, the troops from the revolting colonies of America besieging Quebec were defeated with the loss of their leader, General Montgomery.

Beyond this tablet the road follows the foot of the cliff which reaches its highest point at Cape Diamond, where a slight turn in the road shows a change in the strata to thin-bedded dark shales with interbedded sandstone at a flight of steps leading up the cliff. The shales have afforded a few badly preserved graptolites which suggest that the soft shales are of Lorraine age.

2. *The Northern Face of the Cliff separating Upper and Lower Towns.*

The exposures along this cliff may be reached from the Quebec Ry. Light and Power Co. railway station by crossing St. Paul street and proceeding through the side street to St. Valier, nearly parallel to St. Paul. Following St. Valier west, one crosses Côte du Palais near the site of the old Palais gate, thence the route follows along below the wall of Upper Town. To the right of the stone building in the corner of the wall is the site of the Palais of the old French governors of Quebec. On the left, when nearing St. Rich street, may be seen the limestones, shales and limestone conglomerates of the Quebec City formation. A block further along St. Valier street, the strata can be examined in detail at a stairway on Côte à Cotton, the limestone conglomerate being well shown near the top of the steps, just at the base of a retaining wall. Many of the pebbles in this conglomerate are fossiliferous, the fauna being the same as that found in the pebbles on Mountain Hill.

An iron stairway on the left of St. Peters Church gives another good view of the strata. A short distance beyond this stairway at the Côte d'Abraham is an excellent exposure of the conglomerate, from which a large number of fossils have at various times been obtained.

The Quebec City formation is still to be seen at Côte de la Négresse, beyond which point the cliff is partially concealed by buildings and vegetation, but below the Martello

tower and thence to the Boulevard Langelier, the thin-bedded, grey, micaceous shales of the Lorraine are exposed, with much the same strike and dip as the Quebec City formation. Up the hill, above the shales, the harder shales and limestones of the Quebec City formation have been

Crushed conglomerate with fossiliferous pebbles. Mountain Hill, Quebec.

exposed in trenching for city improvements, and the indications are that the Quebec City is thrust over the Lorraine, instead of the two lying side by side, as in a normal fault. The Lorraine here has afforded numerous specimens of *Diplograptus pristis* and small brachiopods of the genus *Dalmanella*.

Continuing along Arago street the bluff may be climbed at Côte Sauvageau, where the soft shale is in marked contrast to the hard limestone and shales seen at Côte à Cotton and Côte d'Abraham.

After climbing Côte Sauvageau to the point of intersection with Reservoir hill, by descending that hill 200 feet (60 m.), the thin-bedded, soft, grey micaceous Lorraine shales will be encountered. Certain layers in this shale contain a great abundance of graptolites.

A hundred feet further down the hill are hard red sandstones, and from that point west the bluff is composed of shale and clay of the Sillery formations, this being apparently the point of exit of the fault which enters the bluff at Wolfe's Cove on the St. Lawrence side of the city.

Returning up the hill, on a path at the right side of the street formed by the junction of the two hill streets, may be seen a thin bed of limestone conglomerate between layers of the shales. A limestone conglomerate in the Lorraine is a very unusual thing, probably never noted outside this particular area.

From this point also, a good view may be had of the broad, flat-bottomed, deserted channel of the St. Lawrence, a branch of which once flowed to the north of the city.

SPECIAL POINTS OF INTEREST: LÉVIS.

Leaving Main street, at the foot of the bluff about 650 yards (600 m.) east of the railway station at Lévis and proceeding eastward along the Intercolonial Railway tracks, it will be noted that the face of the bluff here, is free from the conglomerate. At the left of the track, however, there is a conglomerate (marked C on map) partly submerged at high water, which strikes toward the railway track, and, in the first cutting crosses the track and forms the face of the bluff to the right. This conglomerate is very different in appearance from those to be seen along the cliffs bordering Main street as it contains more matrix and fewer pebbles, weathers to a peculiar brown, is much streaked with calcite, and contains a good deal of sand.

At the end of this little cutting, this heavy conglomerate disappears. On the left hand side of the track the strata are much disturbed, and while there are two lenses of rusty conglomerate on that side, the main mass of conglomerate does not cross. At the right there is a small offset in the bluff, and on the face a conglomerate like the heavy one just mentioned is seen emerging from the bluff. On the top of the bluff, near St. Joseph road opposite the end of Côte des Pères, this conglomerate is seen again, but cannot be traced much further. It seems that the rusty conglomerate has been thrust by another cross fault a little southward.

About 400 feet (120 m.) furthei along the track, there is another offset in the bluff, and again the rusty conglomerate

seems to be thrown southward, and this time it crosses the track in a small cutting, and disappears.

This cutting is one of the best localities for graptolites in this vicinity, and the position of this graptolite bed in the section is therefore of considerable interest. Up the hill from the graptolite bed is a conglomerate band about 100 feet (30 m.) above it. Fortunately this band can be traced with considerable certainty to connect with the lower of the two bands in the bluff section (conglomerate A., see Lévis guide above). It is of course a question whether the graptolite layers stratigraphically belong 100 feet (30 m.) below this conglomerate A, or 20 feet (6 m.) below the rusty one. It seems that the former is the case, because, firstly, there is a zone of badly crushed and slickensided shale between the lower, rusty conglomerate and the graptolite shale, and secondly, the fauna is like that found in the shales of the bluff, *Dichograptus octobrachiatus* and *Phyllograptus anna* being the more characteristic species.

Beyond this cutting, a path leads up through the bushes to the top of the bluff. Near the top of the bluff is a limestone conglomerate similar to one exposed on the street above St. Joseph road. The conglomerate contains thin-bedded layers of limestone. It is here very thick, but this thickening is due to a doubling on itself in a synclinal fold. Following this path southward, to the highway and thence to and along St. Joseph road to Bégin street and up this street, no strata are exposed until a lane is reached leading to the quarries on the hillside, Just at the entrance to the lane a band of limestone conglomerate is exposed, another occurs a short distance further, and a third makes a prominent ridge just north of the quarries which are themselves in a conglomerate.

In the two quarries opened in this highest ridge there are very large masses of limestone, one of them 35 feet (10·6 m.) in diameter. It is hardly possible to consider them boulders, and, moreover, both these larger masses and the brown weathering paste contain fossils of Beekmantown age. Other pebbles in the same quarry contain Upper Cambrian fossils, and there are some large pebbles of sandstone, notably one just at the left of the eastern quarry. The ridge is therefore a conglomerate, but a large part of the material seems to have come from a limestone layer disrupted *in situ*. The first ridge north of this contains the same sort of large limestone masses

with Beekmantown fossils, and it is thought that the two conglomerates are identical, and form the arch of an overturned and eroded anticline. The two conglomerates exposed to the north in the lane are duplicated in the cemetery back of this ridge.

This ridge is the "ridge north of the St. Joseph cemetery" mentioned by Ells, and it was here that Walcott first found fossils in the matrix and was thus enabled to make a definite correlation with the Beekmantown at Philipsburg.

QUEBEC AND VICINITY: PHYSIOGRAPHICAL NOTES.

(J. W. GOLDTHWAIT.)

The commanding position of the old city of Quebec, on the heights above the St. Lawrence, affords opportunity for observing to best advantage the broader features of the St. Lawrence plain. From Dufferin terrace and the citadel, as one looks down the estuary, he sees on the left the massive forms of the Laurentian mountains stretching away into the distance behind the north shore. Along their irregular border Pre-Cambrian gneisses disappear under the steeply upturned edges of Palæozoic limestones and shales, showing how the long continued denudation of Tertiary time failed by several hundred feet to reduce the crystallines to the level of the adjoining sediments. Midway in the estuary the Island of Orleans with its flat top 250 feet (76 m.) above the St. Lawrence, appears as a connecting link between the narrow plain that lies at the foot of the mountains on the one hand, and the broad lowland of the St. Lawrence on the other. Beneath the smooth skyline of this St. Lawrence plain the river and its small tributaries are deeply intrenched. Here at the narrowest point on the estuary the Plains of Abraham on the north side and the Lévis hills on the south, stand about 300 feet (90 m.) above tide, with precipitous cliffs bordering the St. Lawrence. From the river southward the plain rises slowly and steadily 12 or 13 miles (19 or 21 km.) before it reaches the first definite line of ridges on the southeast. This great St. Lawrence lowland appears to be a peneplain, like the Cumberland, Colchester, and Eastern New Brunswick lowlands, developed on the soft Palæozoic sediments that lie between

the hard gneisses of the Laurentides on the north and the resistant sandstone belts of the Appalachian ridges on the south. Uplifted, like the other lowlands, in mid-Tertiary time, it has been widely dissected by the river and its tributaries, and subsequently drowned. The tide now runs up the St. Lawrence to Lake St. Peter, 80 miles (128 km.) above Quebec. For at least a part of the Pleistocene period the valley stood even more deeply beneath the sea.

According to Chalmers, the glacial history of this region is very complex; for there seem to have been three systems of land ice in the field: first an ice sheet appears to have spread from the Appalachian highlands of southern Quebec and New Hampshire northward as far as the St. Lawrence; next came an invasion of ice from the centre east of Hudson bay which crossed the St. Lawrence as far east as Quebec but not farther; and finally there is thought to have been a southwesward movement of ice from the Laurentian mountains. Local glaciers seem to have descended from these mountains in the closing stages and floating ice drifted up the estuary, which at that time was much deeper and wider. Marks of this drifting ice are found, at various points on the south shore. The evidences of these several stages or epochs of glaciation cannot be regarded as yet sufficiently in hand to justify conclusions regarding them.

At the close of the last Glacial epoch the region around Quebec stood approximately 600 feet (180 m.) lower than now. By a differential upwarping, the old seafloor sediments and associated shorelines have been lifted to their present height above the sea. The obscure character of these raised beaches suggests that the land was already emerging from the sea when the ice sheet melted away, and that it continued to rise rather steadily and rapidly until approximately the present altitude was established. Gravelly beaches on the hills behind Chateau Richer, 15 miles (24 km.) east of Quebec, stop abruptly at 587 feet (178·9 m.). A similar upper limit to wave-washed deposits appears on the road running inland from St. Joachim, 10 miles (16 km.) farther east, at about 570 feet (173·7 m.). At St. Gervais, 15 miles (24 km.) south-east of Quebec, a well built bar of gravel stands 632 feet (192·6 m.) above the sea. These measurements harmonize with those for the upper marine limit along the south

shore, where the water plane rises steadily towards Quebec all the way from Little Metis. Even though marine shells have been found only part way up to this level, as for instance at 375 feet (114·3 m.) at Portneuf, 30 miles (50 km.) west of Quebec, it seems certain that the submergence registered by the gravels at 600 feet (180 m.) is also marine.

Along the electric tramway from Quebec to Ste. Anne de Beaupré, there is an opportunity to see the Micmac sea-cliff and shelf the strongest and most continuous of the old shorelines of the lower St. Lawrence. In the town of Quebec itself, the twenty-foot terrace is obscured by the streets and buildings of the old town. On the Lévis shore several fragments appear. After crossing the delta-like flats at the mouth of the Charles river, near Beauport, the trolley line comes close up to the foot of the steep sea-cliff of this ancient shoreline. From Beauport all the way to Ste. Anne and St. Joachim, at the end of the railway, the cliff is continuous and nowhere far from the track. It is a precipitous turf-covered bank, from 20 to 50 feet (6 to 15 m.) high. While its course instead of being straight is gently curved, there are no marked irregularities, neither bold headland nor sharp re-entrant. It is a typically "mature" coast. From the foot of the cliff the terrace slants gently outward for several hundred yards to the present high tide mark, and continues in the form of half submerged mud flats for an equal distance offshore. Its total width, from the foot of the bluff to the outer edge of the flats ranges from half a mile to a mile and a half (0·8 to 2·4 km.). Across the channel, on the north side of Orleans island, one can see a similar shelf and bluff. This extends completely around the island.

At a number of points along the railway it is possible to see that the cliff has been cut back not simply in glacial drift, but in hard rock. At Eglise de Beauport, for instance, fresh cuts in the face of the Micmac bluff show soft slates dipping seaward at a steep angle, nearly coincident with the slope of the bluff itself. One might conclude that the escarpment was not a wave-cut cliff but merely a structural one, if he saw it at this locality only. At Montmorency Falls, likewise, the red shales, deeply decayed, appear behind the cliff in cross-section in the walls of the gorge. The fall itself lies on the boundary between these shales

and the more resistant gneisses, upon which the river has been held, while it has excavated the deep gorge in the shales below. Continuing along the inner edge of the Micmac terrace to Chateau Richer, the railway passes in sight of quarries on the face of the bluff where limestone instead of shales are exposed. Clearly the bluff has been trimmed back into the coast without regard for the strike or the dip of the rocks. Beyond here the terrace broadens and runs uninterruptedly for many miles.

Two facts about this Micmac shore line are pre-eminent in importance. First, its strength, in view of the narrow limits within which waves could develop between the Island of Orleans and the north shore, is extraordinary. It has been cut back as far into the coast as the distance across the shelf,—or over half a mile. Secondly, the altitude of the shelf here near Quebec is almost exactly the same as its altitude 300 miles (480 km.) down the estuary; and in the interval there are no signs of local warping. This recent emergence of the coast of the lower St. Lawrence within the limits stated was a perfectly uniform uplift.

A study of the flora of the Micmac terrace at Ste. Anne de Beaupré shows a striking intermingling along the high tide zone of salt marsh plants and fresh water plants. This might be interpreted to mean that the fresh marsh is gaining on the salt, and that the plants from the inner marsh are advancing out over the tide marsh as fast as the coast rises. On the other hand, it might be interpreted to mean that the salt marsh plants are invading what was formerly fresh marsh, during a slow subsiding of the coast. And finally, it is possible to regard the intermingling of the two flora as the result of the varying effects of high tides and seasons of heavy rainfall, which now flood the marsh with salt or brackish water and then fill it temporarily with fresh. So far as can yet be discovered, there is no way to demonstrate whether the Micmac shelf is still slowly emerging from the sea, or is stationary, or is slowly subsiding. In general recently collected facts from the New Brunswick and New England coast favour the idea that no change of level has occurred during the last few thousand years.

ANNOTATED GUIDE.

LÉVIS TO RIVIÈRE DU LOUP.

(G. A. YOUNG.)

Miles and Kilometres.

0 m.
0 km.

Lévis (opposite Quebec city)—Alt., 15 ft. (4·5 m.). Leaving Lévis the Intercolonial railway for a short distance closely follows the St. Lawrence shore. It then leaves the river and passing out of the circumscribed area of the Lévis formation, climbs the sharp rise to the level of a rolling, plain-like area underlain by the red and green slates and sandstones of the Sillery formation which customarily has been assigned to the Upper Cambrian though probably of Ordovician age.

The Sillery measures outcrop over a zone having a width varying between 6 miles and 20 miles (9·7 km. and 32·2 km.) and border the St. Lawrence river from the vicinity of Quebec northeastward to beyond Rivière du Loup, over 100 miles (160 km.) away.

To the southeast, the Sillery strata are bordered by a narrower zone of dark slates and quartzites that conformably underlie the Sillery. The Sillery and the underlying formation are strongly folded along axes running nearly parallel with the general course of the St. Lawrence. The folds are asymmetrical, the northwestern limbs being steeper than the southern, and in most places the folds are overturned giving a southeasterly dip, generally with angles of 75° or more.

Within the relatively wide band of the Sillery bordering the St. Lawrence are detached, elongated areas of quartzite and conglomerate composing the Kamouraska formation. These areas vary in length from 10 miles (16 km.) or more down to a fraction of a mile. Their major axes strike approximately parallel with the general strike of the surrounding Sillery. The areas of the Kamouraska are mainly confined to a zone about 45 miles (72 km.) long, bordering the St. Lawrence and situated midway between Quebec and Rivière du Loup.

Miles and Kilometers.

The Kamouraska measures form a series of detached hills seldom rising more than 300 feet (90 m.) above the surrounding country. The strata are sharply folded into anticlines, slightly overturned to the northwest, and pitching both to the northeast and southwest. The conglomerates in places contain limestone pebbles holding Cambrian and in some cases possibly early Ordovician faunas.

The Kamouraska formation has been held by some authorities to be an integral part of the Sillery. J. A. Dresser has, however, brought forward arguments tending to show that the Kamouraska unconformably underlies the Sillery.

For the greater part of the distance between Quebec and Rivière du Loup, the broad band of Sillery is travesred by a zone of overthrust faulting with the downthrow on the northwest side. The fault zone is marked for a length of 65 miles (105 km.) by a well defined escarpment which at the point of the maximum development rises 700 feet to 1,000 feet (215 m. to 300 m.) in a distance of 1 to 1½ miles (1.6 km. to 2.5 km.). This fault escarpment, begins not far from Quebec city and with a curving, irregular front extends northeastward parallel with the St. Lawrence and at a distance inland of 3 to 8 miles (4.8 km. to 13 km.). From the foot of the escarpment a low, fairly level area broken only by a few sharp hills, extends to the St. Lawrence. Inland from the top of the escarpment a rolling upland extends to the southeast for distances of 15 miles to 20 miles (24 km. to 32 km.).

At intervals along the railway route from Quebec eastward, views are obtained of the margin of the Laurentian upland bordering the north shore of the St. Lawrence river. This upland, the Pre-Cambrian protaxis of the continent, rises abruptly from the shore of the river, to heights of 1,000 to 2,000 feet (300 m. to 600 m.). Though in places the upland is rugged and of a mountainous character and though it is

Miles and Kilometers.

nearly everywhere traversed by deeply incised valleys, yet, in general, the upland surface is of the nature of a rolling plateau. At widely separated intervals the foreshore is formed of a narrow fringe of Palæozoic strata, but, elsewhere the Pre-Cambrian rocks directly border the river.

The following note relating to the Glacial and post-Glacial features of the district traversed by the railway between Lévis and Rivière du Loup has been furnished by J. W. Goldthwait.

"In the vicinity of Lévis the eastern edge of the St. Lawrence plain or lowland lies about 13 miles (21 km.) to the southeastward. Beyond this the land rises in a series of ridges which to the northeast gradually approach the St. Lawrence shore. This line of ridges during the period of submergence following the Glacial period formed the shore against which the sea formerly rested. At times a distant view of these hills from the train discloses horizontal benches and lines of low cliffs on the wooded slopes, not unlike certain wave cut benches around the extinct Great Lakes in Ontario. The benches which overlook the marine plain, however, are outcropping rock escarpments, along which proofs of wave action are generally lacking. It is doubtful whether the sea stood long enough at any one time previous to the Micmac stage to cut such sea cliffs. The altitude of the upper marine limit has been satisfactorily determined however, by means of fragmentary benches which harmonize with a gently inclined plane dipping towards the northeast as the following measurements show: St. George eight miles south of St. Charles Junction, 630 feet (192 m.); Montmagny, 543 feet (165.5 m.); L'Islet, 514 feet (156.7 m.); St. Jean Port Joli, 513 feet (156.4 m.). In places, at least, below the level of marine submergence, glaciated surfaces indicate an ice movement straight up the estuary southwestward. The surface of the plain is strewn with crystalline boulders from the Laurentian mountains. Above the level of marine submergence, ground

Miles and Kilometres.

moraine and roches moutonnées and other marks of glaciation appear to indicate an eastward movement of the ice sheet."

13.5 m.
24.14 km.
St. Charles Junction—Alt. 293.5 ft. (89.5 m.). Beyond St. Charles Junction, as the railway descends to the crossing of River Boyer, glimpses may be obtained of the summits of ridges to the southeast, appearing blue in the distance. The front of these ridges marks the position of the zone of faulting that traverses the Sillery area.

23.4 m.
37.7 km.
St. Valier Station—Alt. 156 ft. (47.5 m.). Approaching St. François, the high ridge that bounds the rolling, plain-like area traversed by the railway, gradually approaches the railway and increases in altitude. Near St. François, the red shales of the Sillery are displayed in a railway cutting.

28.5 m.
45.8 km.
St. François Station—Attitude 134 ft. (40.8 m.).

36.7 m.
59.1 km.
Montmagny Station—Alt. 55 ft. (16.8 m.). Just beyond Montmagny, the railway crosses River du Sud and passes close to the St. Lawrence shore. To the southeast, the country rises rapidly for 3 to 4 miles, (5 to 6.5 km.) in a succession of broken ridges to the borders of a highland with a general elevation of 600 to 1000 feet (180 m. to 300 m.).

59.1 m.
95.1 km.
St. Jean Port Joli Station—Alt. 176 ft. (53.6 m). The high ridges, which continue to rise close to the southeast of the railway, are in part underlain by the Kamouraska formation.

66.1 m.
106.4 km.
Ste. Louise Station—Alt. 119 ft. (36.3 m.). Beyond Ste. Louise station isolated, abruptly rising ridges of the Kamouraska formation occur on the northwestern side of the railway.

78 m.
125 km.
St. Pacôme Station — Approaching St. Pacôme, the sillery sandstones and shales are exposed in rock cuttings.

79.7 m.
128.6 km.
Rivière Ouelle—Alt. 48 ft. (14.6 m.).

94.8 m.
152.5 km.
Ste. Hèlène—Alt. 323 ft. (98.4 m.). From Ste. Hèlène to Rivière du Loup the railway traverses a relatively flat area gradually rising

Miles and Kilometres.

inland. The sharp isolated ridges of the Kamouraska strata no longer occur and the quick rise to the south has disappeared.

102.7 m. 165.4 km. **St. Alexandre Station**—Alt. 370 ft. (112.8 m.). "The altitude of the station here is only about 20 feet below that of the uppermost marine beach; and the gentle seaward slope of the plain, with full exposure to the north, offers unusual opportunity for the construction of a beach at this level. From the car window, after the train leaves the station, one can easily see two low, but persistent, gravelly beaches in the fields beside the track, to the south, which run parallel to it for a mile or more. The high broad ridge on whose outer slope they lie is a till-covered ridge of bed rock,—not a beach." (Note furnished by J. W. Goldthwait.)

114.5 m. 184.3 km. **Rivière du Loup**—Alt. 315 ft. (97 m.).

RIVIÈRE DU LOUP.*

(G. A. Young.)

INTRODUCTION.

Riviére du Loup and the adjacent districts are situated within the belt of folded and faulted strata of debatable age that borders the south side of the St. Lawrence river and gulf, from above Lévis to the extremity of Gaspé Peninsula, a distance of about 350 miles (560 km.) These measures belong to the somewhat vaguely defined assemblage of formations known as the Quebec group. The strata of the Quebec group extend southwestward past Lévis to the International boundary and beyond, and in this southwestern extension of the group, it has been possible from palaeontological and other evidence to indicate the existence of many formations ranging in age from Pre-Cambrian to Devonian. In the northeastern extension, however, along the border of the St. Lawrence below Lévis, there does not appear to be the same complexity since by nearly universal consent it has been agreed that the strata

*See Map—Riviére du Loup.

in general belong to one sub-group including members of Cambrian and perhaps early Ordovician age.

The strata in the immediate vicinity of Rivière du Loup have never been described in detail. Logan [**4**, p. 259] merely states that between the coast at Riviére du Loup and Temiscouta lake, "a distance of about 30 miles (48 km.) which is the whole breadth occupied by the Quebec group in this part, no rocks are exposed of a horizon lower than a quartzite formation considered to underlie the Sillery." By Logan, [**4**, p. 233] the Quebec group was tentatively supposed to be of Lower Ordovician age. The quartzites which were thought to underlie the Sillery are stated to have, in other districts, conglomerates with pebbles of limestone, associated with them. The Sillery was tentatively assumed to form the upper member of the Quebec group.

In a succeeeding report [**5**, p. 4], Logan definitely divided the Quebec group into three formations which, in ascending order, were termed, Lévis, Lauzon and Sillery. The Lévis formation was stated to be of about the horizon of the upper part of the Calciferous (Beekmantown).

In the years 1867 and 1868, James Richardson geologically mapped a large area on the south side of the St. Lawrence, extending from above Lévis northeastward to beyond Rivière du Loup. In this general area, Richardson concluded that besides formations belonging to the Quebec group, there was also a development of measures uncomformably underlying the Quebec group and to these older strata he applied the name Potsdam (Upper Cambrian). [**6**, p. 120]. To the Potsdam were assigned the quartzites, etc., which were described by Logan as occurring beneath the Sillery in the Rivière du Loup district and elsewhere. By Richardson the Potsdam was divided into three horizons of which the upper was described as formed of light coloured quartzite passing in places into grey, quartzose sandstone, while in places black shales occur interstratified with the whole mass and at the base is a variable thickness of conglomerate holding limestone pebbles. This division of the Potsdam was stated [**6**, p. 128] to cross Rivière du Loup in a narrow strip just below the High Falls and to be succeeded down stream, by a lower division of the so-called Potsdam. The escarpment which causes the High Falls, was stated to be composed of Lauzon (Quebec group) measures with probably a little of the

Lévis at the base, and it was said that these measures overlie the quartzite of the narrow band of Potsdam below the falls [**6**, p. 132]. The Lauzon is described as consisting of green and red shales with bands of gray sandstone and beds of limestone conglomerate. These calcareous measures were said to be fossiliferous in places, as in the case of an exposure on the banks of Rivière du Loup near the railway station.

During the two decades following 1868, various workers were engaged on problems connected with the Quebec group as developed throughout the long belt occupied by this assemblage. As a result of this long continued effort, radical changes were made in the general conception of the nature and composition of the group. A brief abstract of the views held from time to time has been given by R. W. Ells (**3**). As regards the development of the Quebec group in the area to the northeast of Lévis, the main conclusions arrived at were, that the Sillery was older, *not* younger than the Lévis; the Lauzon division was merged in the Sillery; the Sillery was considered to be of Upper Cambrian age, and the Lévis to be of Lower Ordovician, pre-Trenton age. A division of the Cambrian older than the Sillery was also recognized as existing in the same general region. In the neighbourhood of Rivière du Loup, however, Richardson's subdivisions were discarded and the whole group of strata were referred to the Sillery [**3**, pp. 67-70]. The measures thus treated included the quartzites which both Logan and Richardson had separated as underlying the Sillery.

In a later report by L. W. Bailey and W. McInnes [**1**], the character and structure of the Quebec Group strata as developed over a large extent of territory east and northeast from Rivière du Loup is described, and the conclusion arrived at that virtually all the strata belong to the Sillery division and are arranged in overturned folds with prevailing southerly dips and traversed by thrust faults. It is specifically stated [**1**, p. 22], that there is no apparent reason for the separation as Potsdam of any portion of the strata in the vicinity of Rivière du Loup from any other portions of the series.

Recently, in 1908, J. A. Dresser carried a geological reconnaissance over the greater part of the belt of the Quebec Group lying between Lévis and Rivière du Loup. The results of this work are expressed on a map [**2**] on which

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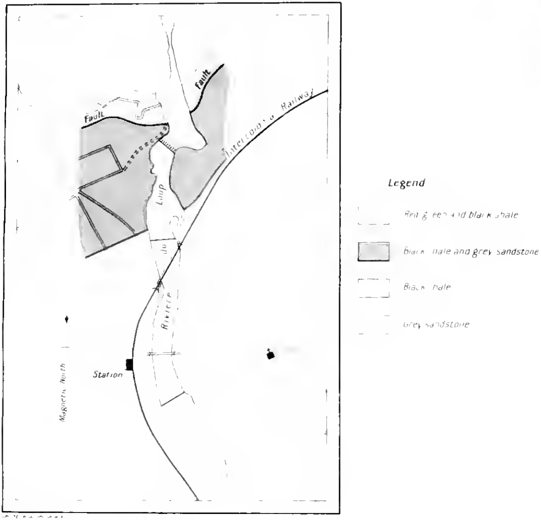

Riviere du Loup

Feet

Metres

however, the geological colouring stops short of Rivière du Loup. It is evident, however, from a consideration of the general geological structure of the region, that according to the views of Dresser, the district in the neighbourhood of Rivière du Loup, is in the main underlain by the Sillery. In the geological legend of the map by Dresser, the Sillery is classified as being of Cambrian age. In the general Sillery area, are isolated areas of quartzites and conglomerates with pebbles of limestone, etc. These rocks are distinguished as forming the Kamouraska formation and by Dresser are considered to be older than the Sillery and possibly to underlie the Sillery unconformably. The areas of the Kamouraska formation as mapped by Dresser, in a general way correspond to one of Richardson's Potsdam divisions, the division to which Richardson assigned the band of quartzite crossing Rivière du Loup below High Falls. It is believed, however, that Dresser would not correlate the quartzite outcropping on Rivière du Loup with the Kamouraska formation.

DETAILED DESCRIPTION.

The foregoing statements present in a generalized fashion, the views previously published regarding the age of the strata occurring at Rivière du Loup in the immediate vicinity of High Falls. In the following statements is given an account of the strata and their structure as observable in a general section along both banks of Rivière du Loup from the neighbourhood of the railway station to below High Falls. The section illustrates, in a general fashion, the nature of a portion of the original Quebec group and of the difficulties in the way of a complete unravelling of the various problems involved.

On lithological and structural grounds, the strata of the section under description are divisible into four groups. The succession descending the river is as follows:—

1. Red, green, and black shale.
2. Black shale, and sandstone.
3. Black shale.
4. Grey sandstone.

By Logan the first three divisions (Nos. 1 to 3) were placed in the Sillery and supposed to be of Lower Ordo-

vician age since the Sillery was thought to overlie the Lévis. By Logan, the grey sandstone (No. 4) was thought to be possibly older than the Sillery. By Richardson, the first three divisions (Nos. 1 to 3) were assigned to the Lauzon (a subdivision of the original Sillery) but guided by the assumed general structure, it was thought possible that the lower portion of the three divisions (Nos. 1 to 3) might be Lévis. The age of the first three divisions was thought to be Lower Ordovician, while division 4 was assigned to the Potsdam (Upper Cambrian) and thought to unconformably underlie the upper three divisions. By Ells, and later by Bailey and McInnes, the four divisions were classed with the Sillery now thought to underlie the Lévis and to be of Upper Cambrian age.

The strata of division 1 as displayed in the neighbourhood of the railway station and along certain streets east of the river, consist chiefly of red, green, and black shales with beds of sandstone and occasional beds of limestone or limestone conglomerate. The strata uniformly dip in a southeasterly direction at angles varying between 45° and 80°.

On the east side of the river along the street leading southerly from the highway bridge over the stream, are outcrops of banded red and dark shales followed by thin bedded, dark grey shales and grey sandstones. The strata dip S. 30° E.,* angle, 70°. Farther on approaching the first street leading to the east, relatively wide bands of red shale alternate with others of a dark grey colour. These are followed by a 20-foot zone of thin limestone beds alternating with dark shales.

On the street leading to the east and past the first road leading to the north, are exposures of banded, red, green and dark purple shales. The strata dip S. 35° E. On the second road leading to the north, no exposures occur until a point is reached about opposite the church. From this point northwards to the end of the street, there is a long series of exposures showing the general character of the rock assemblage.

From this general neighbourhood a splendid view is obtainable of the Laurentian mountains bordering the north shore of the St. Lawrence, 20 miles (30 km.) away.

*All directions of dip are referred to magnetic meridian.

The strata along the above mentioned street from just beyond the church northward to the end of the road, dip in general to the southeast at angles varying between 50° and 70°; that is, if the strata be not overturned, they are displayed in descending order, if traversed in a northerly direction. The first exposures consist of hard, light grey sandstone in beds varying in thickness from 6 to 18 inches (15 cm. to 45 cm.). Beyond this the outcrops consist chiefly of red, green and dark shales, the red varieties predominating. In places the colours rapidly alternate in thin bands, in other places the colour bands are several yards or more wide. Towards the end of the street, where it joins the road leading along the river to the highway bridge, the strata are plicated, perhaps having been involved in a fault zone.

The banded shales are exposed from the end of the street to the railway and there form a long rock cutting. The strata in the railway rock cutting consist of red, green and dark shales with occasional thin beds of sandstone dipping to the southeast at angles varying from 45° to 65°. At two points in the cutting occurs calcareous conglomerate holding pebbles of limestone. At one place, the conglomerate forms a thin, lense-like body, in the other it forms a bed 3 inches (8 cm.) thick. A somewhat similar conglomerate occurs on the west bank of the river opposite the railway station, where the bed is about 4 inches (10 cm.) thick and is associated with dark and red shales. A similar conglomerate outcrops along the railway, south of the station. The following note regarding certain fossils occurring in these conglomerates has been furnished by Dr. Percy E. Raymond.

Note on fossils at Rivière du Loup, Que. By P. E. Raymond.—"Interbedded with the red and green shales at Rivière du Loup are thin layers of conglomerate, the pebbles of which are largely of a grey limestone. Fossils may be found in the pebbles in at least two localities, one on the west bank of the river about 100 feet (30 m.) south of the highway bridge, and the other on the west side of the railroad tracks just south of the engine house. The fossiliferous pebbles are very small, and the fossils fragmentary and unsatisfactory. Pieces of two Orthoids one of them with simple plications, are common at both localities, as are also fragments of the stems of some Pelmatozoan, more probably a crinoid than a cystid. The

most important specimens are two fragmentary Illaenus-like trilobites. These belong to an undescribed genus and species, but the same form is known from the Upper Cambrian of Missouri. This same species was found in a similar conglomerate at St. Phillip de Neri, 31 miles (50 km.) west of Rivière du Loup, but at that locality the greater number of the pebbles contained fossils of Lower Cambrian age, while at Rivière du Loup, no definitely Lower Cambrian fossils have been found. The Upper Cambrian age of the pebbles in the conglomerates is indicated by all the fossils so far found here. In what seem to be these same shales at St. Pascal, Richardson many years ago found graptolites of Beekmantown (Lévis) age".

The evidence of the fossils as given above by Dr. Raymond indicates that the strata of division 1 are not older than Upper Cambrian and that they may be of Beekmantown age.

The boundary between the strata of division 1 and those of division 2 which outcrop along the river below the railway bridge, has been somewhat arbitrarily chosen. From the road which leads from the railway station northwards along the west bank of the river, the red shales and associated strata of the rock cutting along the railway on the east side of the river, are visible, From this road beyond the railway crossing, an occasional glimpse of the red shales outcropping along the river below the railway may be obtained. At a point a short distance below the dam, the red strata abruptly cease and are succeeded by dark rocks which belong to division 2 and outcrop along both banks of the river to a point below the falls.

The strata of division 1 outcropping along the east side of the river below the railway bridge consist of dark shales with sandstone beds and zones of red shale dipping upstream at high angles. What seems to be a minor fault bounding a zone of red shales has been chosen as the boundary between divisions 1 and 2. On the north side of this fault, the strata of division 2 consist of dark, nearly black shales with thin beds of grey limestone, $\frac{1}{2}$ to 1 inch (10 to 25 mm.) thick, dipping upstream at an angle of 60°. The thin limestones, in places, are disrupted and form lenses. Below this point, as far as the brink of the falls, the strata with the exception of several minor bands of red shales, consist of dark shales interstratified with beds of light

coloured, fine grained, quartzose sandstone. At the beginning of the section, the sandstone beds are thin, in most cases from $\frac{1}{2}$ to $1\frac{1}{2}$ inches (10 mm. to 40 mm.) thick, while farther down stream, the sandstone beds bulk more largely and in places are 6 feet (2 m.) thick. The strata in general dip upstream at comparatively low angles, but in places, are crenulated.

The general character of division 2 and its relations with the remaining divisions, may be seen to advantage in the walls of the gorge of the river below the falls. The route to the foot of the falls passes northward through the town and thence by a side street joining a winding road leading down into the gorge of the river. No exposures occur in this part of the town, but presumably it is underlain by strata of division 2. The winding road, leading from the town street, first runs southerly towards a low escarpment whose bare rock face is formed of nearly horizontal dark shales with beds of light coloured sandstone. These measures belong to division 2. They repose on strata of division 3, but are separated from them by a nearly horizontal thrust plane which must lie about at the foot of the escarpment.

At the first bend in the road, in front of the escarpment, and again a short distance farther on, are outcrops of a light coloured, greenish-grey, quartzose sandstone dipping to the southeast, towards the escarpment, at an angle of about 30°. This sandstone belongs to division 4, and in the exposureless interval between its outcrops and the face of the escarpment, must lie the strata of division 3.

The strata of division 3 are displayed along the road from a point near the second exposure of sandstone, to near the end of the road at the river side. In the first exposures, the strata dip southwards at angles of about 45°. The rocks consist of dark shales with thin sandstone beds $\frac{1}{2}$ to $1\frac{1}{2}$ inches (10 mm. to 40 mm.) thick. As the road is descended, there may be seen in the high rock escarpment the trace of a thrust plane along which the strata of division 2, have been pushed over those of division 3. The fault plane dips towards the south at an angle of about 20°. The overlying strata of division 2, are nearly horizontal, the underlying strata (division 3), are steeply inclined and, in the neighborhood of the fault, are crumpled and torn.

From the underlying shales of division 3, Dr. Raymond has collected fossils of a single species, regarding which he makes the following note. "The small flattened oval fossils are *Caryocaris curvilineatus*, Gurley. Both genus and species are confined, in this general region, to rocks of Lévis age. The species has been found at Point Lévis, Deepkill, near Albany, N. Y., and in Nevada, while the genus occurs also in the Skiddaw slates of England and Australia."

The finding and identifying of this fossil corroborates in a certain measure Richardson's suggestion that possibly these underlying measures might belong to the Lévis, though Richardson's belief was founded, as it is generally supposed, on a mistaken supposition regarding the relative ages of the overlying and underlying strata.

From the edge of the river, the trace of the thrust plane is visible in the cliff face rising from the opposite shore. The overlying strata of division 2, may be seen to be thrown into a series of crenulations clearly and strikingly expressed by the banded character of the measures. The regularly-formed crenulations or plications, perhaps average 4 to 6 feet (1·2 to 1·8 m.) from crest to crest. These crenulations extend up the whole height of the high, cliff face. Along this rock face upstream, the plications gradually fade away and towards the head of the rock-walled, amphitheatre-like embayment, the strata dip regularly to the southward at angles of from 35° to 45°. The strata of division 2, thus exposed at the head of the amphitheatre-like embayment are separated by a concealed interval of about 30 feet (9 m.), from the red and dark green shales of division 1, exposed in the long rock cuttings on the railway line.

The strata of division 3, consisting chiefly of dark shales, outcrop along the shores of the river for a distance of about 200 feet (60 m.), or as far down the river as the place where the river channel commences to narrow. At this place are outcrops of light coloured, quartzose sandstone interbedded with shales. The strata dip southward at an angle of 35°. These ledges mark the position of the assumed northern boundary of division 4. The sandstone, in heavy beds with interbeds of dark shale, outcrops down stream for a further space of about 200 feet (60 m.). Beyond this, exposures cease and no more outcrops occur for a long distance downstream. The sandstones are lithologically ve y similar to the sandstones

associated with the limestone conglomerate at Bic and resemble the sandstones and associated conglomerate of other localities.

The sandstones of division 4, are, apparently, conformable with the shales of division 3. If, as the single fossil species seems to indicate, the shales are of Lévis age, then the quartzites are also of this age. The strata of divisions 2 and 1 seem to be conformable, though locally separated by a break. The fossils recovered from division 1 indicate that the strata are not older than Upper Cambrian: they may be of approximately the same age as divisions 2 and 4.

The structures exhibited by the strata of division 2 in the cliff face below the falls—the gradual change in attitude from an inclined one to a nearly horizontal, plicated one, and the fact that the zone of plications does not bear any evident relation to the plane of the thrust fault—indicate that the measures lie in a deformed, overturned anticlinal fold, which during the process of folding was plicated at the apex. If this be so, then, as the existence of the thrust fault and the uniform direction of the dip of the strata both above and below the fault indicate, a thrust fault developed after the fold was overturned, whereby the upper portion of the recumbent fold was thrust forward over the overturned, lower limb so that stratigraphically lower measures came to lie on stratigraphically higher measures. This general conclusion apparently is supported by the somewhat meager fossiliferous evidence so far obtained. If the above suppositions are correct, it follows that the quartzites of division 4, are the youngest strata exposed in the section and not, as at one time thought, the oldest. On the above general grounds, the true order of succession of the strata of the section in descending order is,—

Division 4, grey quartzose sandstones with interbedded dark grey shales.

Division 3, dark grey shales.

A section of strata unrepresented because of the presence of thrust fault.

Division 1, red ,green and dark shales, with beds of limestone conglomerate, limestone and sandstone.

Division 2, interbedded dark, grey shales and light coloured sandstones.

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RIVIÈRE DU LOUP.

THE POST-GLACIAL MARINE SUBMERGENCE.

(J. W. GOLDTHWAIT.)

At Rivière du Loup terraces and benches at various levels on the slaty hillsides offer little that is reliable as an index to the extent of marine submergence. In the southwest part of the town, however, two rather delicate gravelly beaches may be traced through the fields, at a height of 372 feet. Inasmuch as this measurement at Rivière du Loup harmonizes with those at other places along the coast, lying on the same inclined plane, it seems safe to accept it as the upper limit of submergence. This agrees perfectly with the determination made by Baron De Geeri n 1892* Just beyond the car shops a ditch beside the Intercolonial railway showed in August 1912, a very fine cross section of a shell bed 340 feet above sea level. This is not only the highest occurrence of Pleistocene marine shells east of Quebec, but one of the rare instances of marine shells close to the upper limit of submergence. The unusually large size of the *Saxicava arctica* and the profusion of them in these old tidal flats

*G. De Geer: On Pleistocene changes of level in eastern North America. Boston Society of Natural History, Proc.; vol. 25, 1892, pp. 454--477; and American Geologist, vol. 11, 1893, pp. 22--24.

at the mouth of the Riviére du Loup, indicates that conditions for life here were exceptionally favourable. Several other types of shells occur in the deposit, but fully 95 per cent are *Saxicava*. Heavy gravels of this delta, but barren of fossils, are exposed across the river, not far from the railway station.

ANNOTATED GUIDE.

RIVIÈRE DU LOUP TO BIC.

(G. A. YOUNG.)

Miles and Kilometres.

0 m. 0 km. **Rivière du Loup**—Alt. 315 ft. (96·m.). From Rivière du Loup to Bic, the St. Lawrence river is bordered by a wide zone of the same general succession of strata traversed by the railway from Quebec eastward. The measures consist largely of red, green, black, and grey slates with bands, mostly of limited extent, of quartzose sandstone. With these occur beds of sandstone and of conglomerate bearing limestone pebbles and boulders. The strata in general strike parallel with the St. Lawrence shore but are everywhere much folded and contorted; overturned folds and faults occur at many points. The strata in general have been usually regarded as being of Cambrian age. The measures in the neighbourhood of the coast were considered by Logan to underlie the Sillery formation. With the exception of the fossils recovered from the limestone fragments in the conglomerates, the only fossil recorded from the strata of the district is *Obolella pretiosa*. The zone of these measures extends inland at Rivière du Loup for about 30 miles (50 km.). Farther east, the zone decreases in width and at Bic it is only about 7 miles (11 km.) broad. These Cambrian or Ordovician measures are bounded on the south by Silurian strata consisting largely of intricately folded dark slates.

Leaving Rivière du Loup the Intercolonial railway for a number of miles, passes along or near the steep drop leading to the low lying

Miles and Kilometres.

land bordering the St. Lawrence. To the southward the country rises gradually inland in a broken, rolling fashion.

27 m. 43·5 km. **Trois Pistoles Station**—Alt. 112 ft. (34·1 m.). On the shore at Trois Pistoles, in a measured section of 700 feet (213 m.) of strata, 150 feet (47·7 m.) consist of grey calcareous sandstone and conglomerate. The conglomerate occurs in nine beds 2 to 16 feet (0·3 to 4·9 m.) thick. The rounded masses in the conglomerate are chiefly of limestone weighing from a pound to a ton (1,000 kilos).

35·6 m. 57·3 km. **St. Simon Station**—Alt. 296 ft. (90·2 m.). The railway passes through a succession of comparatively wide valleys whose bounding ridges gradually increase in height. These ridges are presumably largely formed of resistant quartzose sandstone. The bounding ridges on the north, though parallel with one another, slightly overlap. It is probable that this feature is indirectly due to the faulting of the resistant bands of quartzose sandstone.

Approaching St. Fabien banded red and green, and dark slates are exposed in rock cuttings. The strata are crumpled and contorted.

45·5 m. 73·2 km. **St. Fabien Station**—Alt. 445 ft. (135·6m.). From St. Fabien to Bic, high abrupt ridges rise to the northeast of the valley traversed by the railway. Approaching Bic, these ridges as seen from the railway, possess very steep faces on their seaward sides while on the landward sides, the slopes are more gentle. The hill forms apparently conform in outline to the general southerly dip of the strata.

At intervals along the railway, are exposures of slates and quartzose sandstone.

54·8 m. 88·2 km. **Bic**—Alt. 82 ft. (25 m.).

BIC.*

(G. A. Young.)

INTRODUCTION.

Bic, like Rivière du Loup, is situated within the long extended zone of the Quebec group, which borders the south side of the St. Lawrence from opposite Quebec city nearly to the extremity of Gaspe peninsula. A certain amount of prominence in geological literature has been given Bic and other neighbouring localities because of the occurrence of conglomeratic strata containing, in places, fossiliferous limestone pebbles. Somewhat similar conglomerate beds occur at various horizons in the Quebec group and at intervals throughout the whole extent of the group from Lévis northeastward. These occurrences of conglomerates differ amongst themselves in that in some cases the fossils of the pebbles may represent an assemblage of distinct faunas ranging in age from Lower Ordovician to Lower Cambrian; or the fossils present may all belong to one general fauna, as in the case of the conglomerates at Bic where fossils of Lower Cambrian age only, have been recovered.

One general characteristic is common to all the known fossiliferous conglomerate horizons,—the original source of the fossiliferous strata has not been established and, though the present borders of the Laurentian Pre-Cambrian area lies so close, yet pebbles or boulders of typical Laurentian rocks are exceedingly rare if not in most cases entirely absent from the conglomerates.

The following statements regarding the fauna occurring in the conglomerate in the vicinity of Bic have been prepared by Charles D. Walcott.

'The fauna occurring in the boulders and limestone at Bic harbour is that found in the later deposits of the Lower Cambrian rocks both in Newfoundland and the St. Lawrence valley, also in some of the older deposits of the Lower Cambrian. It is marked by the presence of *Olenellus thompsoni*, which occurs in the later deposits

*See Map—Bic.

both on the Straits of Belle Isle and in the Lake Champlain valley. The presence of *Hyolithellus micans*, *Microdiscus lobatus*, and *M. speciosus* indicates that there is also present a portion of a somewhat older fauna than that occurring with *Olenellus thompsoni*.'

'The origin of the boulders containing the Olenellus fauna is unknown. There is a marked lithological and palæontological similarity between them and the Lower Cambrian limestone of Topsail head and Conception bay, Newfoundland, that points to similar conditions of sedimentation and life, and I found the head of an Olenellus on the Island of Orleans that is of the type of *O.* (*M.*) *bröggeri* of Newfoundland. It is quite possible that the deposits from which the conglomerates were derived extended around the Newfoundland coast, to the west and north, and thence along the margin of the Pre-Cambrian land, southwest, toward the Adirondack mountains of New York, and that the disturbances toward the close of the Cambrian period, in the St. Lawrence valley, resulted in the uplifting of the Lower Cambrian strata and its denudation and breaking up during Upper Cambrian and Lower Ordovician time.'

'From Bic harbour, Trois Pistoles, and St. Simon the following species have been found in the conglomerate limestone:—

Lingulella caelata	Agnostus sp.?
Iphidea bella,	Microdiscus lobatus,
Kutorgina cingulata,	Microdiscus speciosus,
Obolella crassa,	Olenellus thompsoni,
Obolella circe,	Olenoides marcoui,
Obolella gemma,	Olenoides levis,
Orthis, 2 n. sp.,	Ptychoparia adamsi,
Platyceras primaevum,	Ptychoparia teucer,
Scenella retusa,	Ptychoparia (?) trilineata
Stenotheca rugosa,	Ptychoparia, sp. undt.
Hyolithes americanus,	Agraulos strenuus,
Hyolithes communis,	Protypus senectus,
Hyolithes princeps,	Protypus senectus, var. parvulus,
Hyolithellus micans.	

'The above fauna proves clearly that there was a large and varied Lower Cambrian fauna in the limestone from which the boulders of the Bic conglomerates were derived,

and that the fauna is essentially the same as that of the Lake Champlain and Upper Hudson river area in eastern New York.'

The conglomerates which are displayed so prominenty at Bic and for some distance to the southwest and northeast, are confined to a comparatively narrow belt along the coast. They occur in conspicuous ridges surrounded or alternating with low-lying areas occupied by shales and slates. The prominence thus given to the conglomerates, their interesting features and their situation on the coast, has naturally directed the attention of geologists to them, but in spite of this, comparatively little detailed information has been recorded.

Since the fossils found in the conglomerates occur in pebbles, it is evident that the fossiliferous evidence fixes only the lower limit of the possible range of age of the beds; the conglomerate cannot be older than the age of the fauna represented in the pebbles and boulders. Consequently any attempt to more definitely determine the age of the conglomerates must be based on other lines of evidence.

James Richardson in two early reports [**2,** pp. 126–7, p. 149; **3**, p. 130] assigns the Bic conglomerates to a position stratigraphically beneath the Sillery. In a much later report, L. W. Bailey and W. McInnes [**1**] assign the Bic conglomerates to a horizon in the upper part of the Sillery (Cambrian). It is stated [**1,** p. 22] that, in general, the conglomerates are displayed along synclinal or anticlinal axes. The general succession of the strata is stated to be as follows arranged in descending order,—

(a) Fine grained sandstone or quartzite, grading downwards into,

(b) Conglomerate and sandstone grading downwards into,

(c) Comparatively coarse conglomerate, resting on,

(d) Red, green and purple slates.

This general arrangement, it is stated, obtains at Bic, where besides the main band of conglomerate, other smaller bands occur.

DETAILED DESCRIPTION.

In the limited area bordering Bic river and the eastern end of Bic harbour, represented on the accompanying

geological sketch map, the strata consist of zones or bands of quartzose sandstone or quartzite and conglomerate alternating with bands of shale or slate. The strata, in a general way, strike east and west and are traversed by a series of faults striking to the west of north. The fault planes are presumably vertical or nearly so and in the cases of all the faults observed the strata on the western side of the fault plane, relatively to the strata on the eastern side of the fault, are displaced towards the north. Besides these more easily detected faults that strike in a northerly direction, there are also present others striking in an east and west direction.

The strata of the zone of quartzite and conglomerate traversed by Bic river, south of Bic harbour, is, in its northern portion folded into an open synclinal form, and the quartzites and conglomerates therefore overlie the dark shales exposed along the railway. Possibly the two bands of quartzite on the northern side of the estuary of Bic river, represent tightly compressed folds of the same quartzite horizon, but the evidence is not complete in this respect. In the case of the broad belt of quartzite and conglomerate south of the railway, the southern portion, south of the synclinal axis referred to, apparently is folded into an anticline, and along the southern border of the area, the quartzites dip steeply beneath dark shales interbedded with light coloured, fine grained sandstones.

Fossils occur in the conglomerates at Bic at a number of points. One of the more readily accessible of these is a short distance west of Bic station and to the south of the railway. The first conglomerate band south of the railway, at this point, contains many fossiliferous limestone pebbles, in which the most common fossils are *Olenellus thompsoni*, *Protypus senectus* and *Microdiscus*.

The general geological structure and the nature of the stratigraphical divisions may be observed if the road leading southward from Bic station is traversed as far as the crossing of Bic river, and if also the road leading northwestward along the eastern side of Bic harbour is followed to its ending.

A very short distance west of Bic station and immediately south of the railway, there rises a partly wooded ridge extending for some distance west of Bic but ending abruptly on the east just south of Bic station. This ridge is formed

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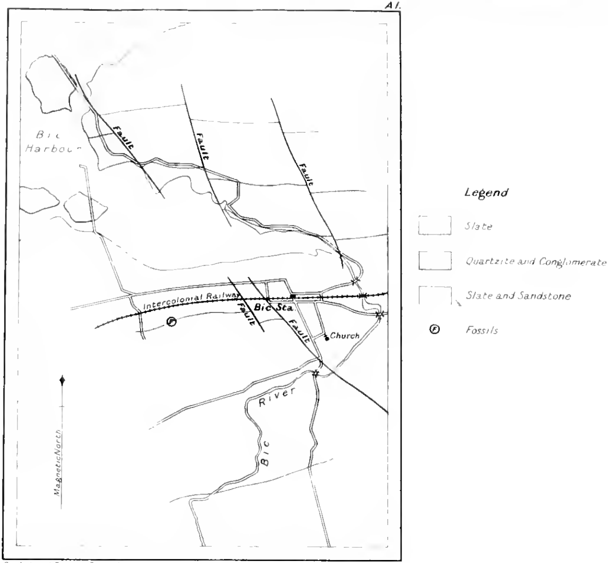

Geological Survey Canada

Bic

Feet 500 0 500 1000 1500 2000

Metres 100 0 200 400 600

(Scale of map is approximate)

of alternating beds of coarse and fine quartzite, and conglomerate either disposed vertically or dipping to the south. At the foot of the northern slope, the quartzite and conglomerate are interbedded with black slate, while along the railway line the strata are entirely composed of black slates. The interbedding of the quartzites and slates along the boundary of the two divisions and the absence of any appearances of structural unconformity indicate that the slate series and the quartzite series are conformable, while the uniform southerly direction of dip in the eastern part of the ridge and an open synclinal fold developed to the south indicate that the quartzite series overlies the black slate division.

The road leading southward from Bic station ascends a gently rising slope and passes a few hundred feet to the east of the abrupt end of the quartzite ridge. Along the roadside are exposed nearly vertical beds, striking westward, of purple weathering dark shales; these shales at the southern end of the exposure contain thin beds (1 to 6 inches; 2 cm. to 15 cm.) of fine-grained sandstone and these dip southward at an angle of 60°. The slates strike directly towards the quartzite ledges exposed along the east slope of the hill and, evidently, must be separated from them by a fault plane.

No further outcrops occur along the road for some distance. As the road is followed southward, the outcropping ledges of white quartzite to the west, may be seen to approach closer and closer to the road. Just beyond where a branch road leads to the west and close to the Bic river, an exposure of dark weathering, greenish slate occurs on the roadside while, just beyond at the turn of the road, are outcrops of quartzite and conglomerate. These two exposures are believed to lie on opposite sides of the above mentioned fault plane. In the general area to the east of the fault plane,—along the river, over the ridge on the southern side of the river, and elsewhere, only dark slates and the associated thin beds of sandstone are exposed. West of the fault plane the strata are almost entirely light coloured quartzites and conglomerates.

At the bridge over the river the quartzite beds are displayed in the crown of an anticline. On the river below the bridge, the quartzites dip southerly at angles of 20° to 30°, while those above the bridge dip at low angles to

the north. Both above and below the bridge dark shaly measures are interbedded with the quartzites and outcrop from beneath them, and it is assumed that these beds mark the summit of the shale division underlying the quartzites. To the south on the southern limb of the anticline, the quartzites and conglomerates dip at high angles to the south or are vertical. Along the southern boundary of the quartzite area, the strata dip southward at angles of from 60° to 80°, and disappear beneath an overlying series of dark shales with interbedded sandstones. To the north of the river, the strata on the north limb of the anticline dip at low angles to the north, but just north of the road leading west, the measures are traversed by a synclinal axis and the direction of dip rom this point to the north brow of the hill is to the south.

The dark slates on the east side of the major fault noted above, are exposed along Bic river as far down as the railway crossing. A small outcrop of these rocks occurs in front of the parish church. The slates everywhere dip to the south at high angles. These beds thus appear to form the northern limb of a syncline, though it is possible they form the limb of an overturned anticline. If the shales respectively to the east and west of the major fault belong to the same horizon, the more natural assumption, and this is the one adopted, would be that the strata lie in the northern limb of a syncline.

From the square in front of the parish church, looking northward across the railway and beyond an open field, a low ridge of light coloured rock may be seen separated by a low-lying interval from a much higher ridge to the north. Both ridges strike in an east-west direction and are formed of quartzites and conglomerates. The intervening, low ground is underlain by dark slates.

No exposures occur along the road leading northward from the church to the railway nor do any occur for some distance along the shore road skirting the eastern side of Bic harbour. At the falls on Bic river at the railway bridge, dark shales with thin sandstone beds dip in a southerly direction at an angle of 55°. A ten-foot bed of limestone conglomerate forms the projecting rib of rock which is the immediate cause of the falls. Along the shore road, to the north of the crossing of Bic river, the first exposures are of conglomerate. The conglomerate as seen on a weathered surface, consists of a mass of rounded

and angular, light coloured fragments lying with very little evidence of bedding, in a dark matrix of the nature of a coarse, quartz sandstone or quartzite. The embedded fragments vary in size from very small up to one foot or more in diameter, and when broken out from the matrix may be seen to possess smooth, rounded, waterworn outlines. As may be noticed in this and other exposures, certain beds of the conglomerate are characterized by the uniformly small size of the contained fragments, others by the relatively large size of the fragments. The fragments consist chiefly of limestone, the most abundant variety being a dense, bluish-grey type. Pebbles and boulders of sandstone, quartzite, quartz, limestone conglomerate, sandstone conglomerate, etc., are also present.

Towards the west end of the exposure of conglomerate, a small body of dark shale is exposed on the roadside in contact with the conglomerate. The same dark shale or slate is exposed westward along the shore. Apparently this locality is at the contact of the conglomerate with the large body of shales extending to the south. If it be true, as has been assumed, that the shales lie on the northern limb of a syncline, then the conglomerate and quartzite band to the north belongs to a horizon lower than that of the body of similar strata forming the ridge southwest of Bic station.

Westward from the exposure of conglomerate, the highway approximately follows the boundary between the conglomerate and quartzite on the north, and the shales on the south. The line of contact between the two divisions is very irregular in detail probably as a result of deformation that took place during the folding and subsequent faulting of the measures when, doubtless, the shales as a whole acted as a relatively plastic body and the conglomerates and quartzites as a brittle mass. Along this portion of the road, the quartzite beds associated with the conglomerates, are exposed. The quartzite composes the bulk of the formation. It is usually fine grained but in places is sufficiently coarse to be termed a grit and is composed almost exclusively of rounded quartz grains in a silicious matrix.

No rocks outcrop along the road where, after passing through a cut in conglomerate, it bends to the eastward along the edge of the low ridge. The quartzites and conglomerates in this ridge are vertical or dip steeply to the

south. It may be assumed therefore, that these measures also lie in the northern limb of a syncline.

Along the road where after following a northerly course for a short distance, it again turns and strikes to the west, several exposures of conglomerate occur to the south of the road, while on the road and in the fields on the north side are outcrops of dark shale. A short distance farther on in a low, small knoll, the conglomerate and the slaty rocks are displayed in contact with one another, the strata dipping steeply to the south. The road, apparently, follows the northern boundary of the belt of conglomerates and quartzites.

At the place close to the shore where the road bends to the north, several hummocks of conglomerate occur on the east side of the road; their presence apparently indicates the existence of a north-south fault lying just east of the exposures. Northward, along the road, a single exposure of dark shale occurs before the ending of the road at the pier which apparently is situated almost directly on the course of the above mentioned fault, the presence of which is indicated in the strata exposed at low water along the eastern side of the pier.

At the beginning of the pier, conglomerate and quartzite are exposed to the east. The strata are much fractured and are veined with calcite. These measures form the prominent ridge which fronts on the coast and extends for several miles to the east. Similar strata are exposed on the island on whose side the pier is built, and the general characters of the conglomerate and quartzite are excellently displayed in large exposures.

On the island the strata dip towards the north at comparatively low angles. It is inferred that the strata of the ridge along the coast occur in the form of an anticline probably deformed by faulting, and that this band of conglomerate and quartzite dips beneath the first zone of dark slates to the south, and that these in turn dip beneath the strata of the succeeding band of quartzite and conglomerate.

The general inferred succession of the strata displayed in the immediate vicinity of Bic is as follows, arranged in descending order,—

(a) Dark slates with interbedded sandstone.
(b) Quartzite with interbedded conglomerate.

(c) Dark slates, in places weathering with a purplish colour; occasional relatively thin beds of limestone conglomerate.
(d) Interbedded quartzites and conglomerate.
(e) Dark slate.
(f) Conglomerate and quartzite.

The total thickness of the series displayed must be considerable, perhaps in the neighbourhood of 3,500 feet (1,066 m.), but no reliable estimate of the thickness has been formed. Regarding the age of the strata it may be stated that it cannot be older than Lower Cambrian since the fauna of the limestone pebbles in the conglomerates is of this age. Presumably the series is at least as young as Middle Cambrian and possibly still younger. It is noteworthy that lithologically the quartzites are identical with the quartzite or quartzose sandstone displayed at Rivière du Loup below High Falls. The somewhat scanty fossiliferous evidence obtained at Rivière du Loup indicates that there the quartzite is of Lower Ordovician age; possibly the strata at Bic are of about the same age.

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BIC: THE POST-GLACIAL MARINE SUBMERGENCE.

(J. W. Goldthwait.)

Just to the west of Bic railway station one may see a record of glaciation towards the north,—according to Chalmers' interpretation—by the ice from the Appalachian highlands. A well formed roche moutonnée close beside the track is severely scrubbed on the south side and torn and roughened on the north. Among the ledges of limestone and conglomerate which outcrop in the hills south

of the railway, well formed pocket beaches may be seen. Unlike the prevailing slate of the St. Lawrence plain, which splinters and flakes in a most unfavourable way for beach construction, the limestone supplied the waves with an abundance of good pebble making material. Here, therefore, is one of the most satisfactory places on the whole coast of the St. Lawrence to determine the height to which the sea has washed the surface. A mile or two southeast of the station, the upper marine limit is very distinctly marked by a set of gravelly beaches

Micmac bluff and terrace at Bic, Quebec.

that stop abruptly at 311 feet (94·8 m.). On ledges slightly above this level, the thickly scattered joint fragments of limestone show no sign whatever of rounding and assorting. No marine fossils have been discovered in these highest beaches; in fact, discoveries of shells at the extreme upper reach of submergence are rarely made. Fossils of sub-arctic species may be collected, however, from the deeper water clays at 120 feet (36·5 m.) two miles east of the station on the road to Hattie bay. On the

north side of the railway the village of Bic extends out to the brink of the old Micmac sea-cliff, which reappears here with all its characteristic freshness and strength. The great length of the Micmac stage is the more evident when one compares the great sea cliff with the low bank and marshy beach at the modern high tide mark. The last twenty feet of the whole 311 feet (94·8 m.) elevation of the coast at Bic seems to have been accomplished only after centuries of stability or of slow coastal subsidence; and judging by the ineffectiveness of the modern waves this renewed uplift may still be going on.

ANNOTATED GUIDE.

BIC TO MATAPEDIA JUNCTION.

(G. A. Young.)

Miles and Kilometres.

0 m.
0 km.

Bic—Alt. 82 ft. (25 m.). From Bic to Matapedia Junction the Intercolonial railway for about 100 miles (160 km.) or as far as Little Metis, parallels the St. Lawrence river either passing close to the shore or inland at a distance of several miles. Throughout this distance the railway traverses a portion of the belt of 'Cambrian' strata that borders the St. Lawrence on the south side from Quebec city eastwards. As in the sections between Quebec and Bic, the strata are largely red, green and black slates with bands of sandstones, and local developments of quartzose sandstones and conglomerates containing fragments of fossiliferous limestone. The measures in general strike parallel with the St. Lawrence, but are closely folded and much faulted. The 'Cambrian' strata of this belt are bounded on the south by a wide area of Silurian limestones.

At Little Metis the course of the railway turns inland, runs in an easterly direction across the full width of the belt of 'Cambrian' measures, and entering the Silurian and Devonian area of the Shickshock mountains, runs first

Miles and Kilometres.

southeast and then south across the axis of the mountains by way of the Matapedia valley. The Silurian and Devonian strata of the Shickshock mountains occupy the greater part of the Gaspe peninsula and in Canada, extend southwestward from the eastern extremity of Gaspe peninsula to beyond the Temiscouata river, a distance of about 250 miles (400 km.). In age the measures range from Niagara or younger to late Devonian, and apparently form a conformable group. The Silurian measures are largely dark grey slates and calcareous slates, but limestones occur at various horizons, more especially towards the top of the series. The lower Devonian measures are largely slates, calcareous slates, and limestones. The upper Devonian strata are dark grey shales and sandstones containing, in places, an abundance of plant remains. The strata in the extreme eastern portion of Gaspe peninsula strike in general, somewhat south of east; towards the centre of the peninsula the general strike is east and west; farther west, in the Matapedia valley the general strike is about south-southwest; while still farther west, the general strike is southwest. Over a considerable portion of the peninsula the measures lie in broad open folds, but in many parts and over large districts the strata are closely folded and are traversed by numerous dislocations.

After leaving Bic, the railway approaches and closely follows the shore where, as near Sacré Coeur, dark slates outcrop with low angles of dip.

6·3 m. 10·1 km. **Sacré Coeur Station**—Alt. 20 ft. (6 m.). 'The view of the great Micmac cliff and terrace near Sacré Coeur is very instructive. On the left hand side of the track is the steep, straight wave-cut bluff, whose base is approximately 20 feet (6 m.) above mean tide. Slate outcropping along the face of it shows that the waves at this stage cut back with power and persistence for a long period of time. On the other side the gravelly wave swept terrace,

Miles and Kilometres.

now well out of reach of the sea, stretches forward to the water's edge, and merges almost imperceptibly with the tide-covered flats which run out as far as the eye can see. These mud flats are in many places so thin that the wave-bevelled edges of the layers of slate show through them, testifying to the complete planation of the Micmac shelf by the sea at the time when it was advancing against the cliffs. The indefinite, expressionless beach which lies along the line of modern storm waves, half concealed by salt marsh grass, is insignificant as a record of wave rock, in comparison with the great sea-cliff that marks the twenty-foot stage. These vast mud flats, which follow the south shore all the way to Quebec, are plainly the still submerged outer portion of the Micmac terrace and not the product of wave action at the present level save for the soft muddy sediment which scarcely conceals the rock surface, and the ice-rafted boulders which lie scattered abundantly over the shallow water zone. The upper marine beaches, also, which lie out of sight of the railway, on the upland above the old sea-cliff, are comparatively indistinct. The highest one stands at 294 feet (89·6 m.). Three-quarters of a mile beyond Sacré Coeur, the Micmac sea-cliff attains its greatest strength, rising precipitously over a hundred feet above the shelf on which the railway runs. It is important to note that through this whole district the altitude of this terrace is constant, and continues without change all the way to Quebec." (Note supplied by J. W. Goldthwait.)

Approaching Rimouski, cuttings in dark slates occur along the railway.

10·5 m. **Rimouski Station**—Alt. 54 ft. (16·5 m.).
16·9 km. Beyond Rimouski, the railway swings away from the shore and traverses a low, gently rolling country bounded inland, by a series of parallel ridges. Approaching Ste. Flavie, the country is more broken, the ridges inland are

Miles and Kilometres.

higher and still higher ones are visible in the distance.

28·5 m. 45·8 km. **Ste Flavie Station**—Alt. 266 ft. (81 m.). "At Ste. Flavie, the station stands within a few hundred yards of the upper marine limit, which is marked by an obscure sandy beach in the house lots on a back street southeast of the track. It is 272 feet (82·9 m.) above sea level. Beyond, on higher slopes the form and composition of the ground indicate that no submergence has taken place. Between the 272-foot beach and the shore of the St. Lawrence are a number of gravelly beaches. Three miles beyond St. Flavie, the valley of Grand Metis river is crossed. Looking up the valley, high ridges are visible. The flat ground on both sides of the river, here, is the top of an extensive delta, built during the emergence of the coast from the sea. Its altitude, about 260 feet (79·2 m.) above sea level, corresponds closely with the altitude of the highest beach at Ste. Flavie. At Priceville, a large lumber town at the falls of the Grand Metis river, within sight of the railway bridge, the delta gravels contain myriads of mussel shells, at an altitude of about 175 feet (53·3 m.)." (Note supplied by J. W. Goldthwait.)

Beyond the crossing of Grand Metis river, rock cuttings in dark slates occur along the railway which, gradually rising, passes along the edge of a steep drop to the low foreland bordering the St. Lawrence. From this section is obtained a last view of the Laurentian highlands on the north side of the St. Lawrence, 30 miles (50 km.) away.

The railroad finally turns to the east and entering the valley of Little Metis river crosses the band of Sillery and associated strata which has continued uninterruptedly from Lévis, 190 miles (300 km.) to the southwest and which extends for 165 miles (265 km.) farther to the northeast, to the extremity of Gaspe peninsula. In the extension of this band to the northeast, graptolite-bearing shales of Utica age (Upper Ordovician) are infolded with the older measures.

Miles and Kilometres.

38·6 m. 62·1 km. **Little Metis Station**—Alt. 569 ft. (173·4 m.). Little Metis station is high on the side of the valley of Little Metis river which the railway follows upwards for a few miles passing through many rock cuttings in red and dark slates, and sandstones. The strata in some of the rock cuttings are highly contorted.

Leaving the Little Metis valley, the railroad continues to ascend through a rough, broken country.

42·5 m. 68·4 km. **Kempt Station**—Alt. 688 ft. (209·7 m.). Beyond Kempt the railway passes through rock cuttings in red and black slates. The railroad then follows up the valley of a small stream with rock walls of dark slates.

50·5 m. 81·3 km. **St. Moise Station**—Alt. 540 ft. (195 m.). In the neighbourhood of St. Moise an extensive view is afforded to the northeast over a low, broken country with one rather high hill nearby. Rock cuts in red and black slates occur along the railway which at a point several miles east of St. Moise, passes over a low summit, altitude 771 ft. (235 m.) and drops to the shores of a small lake draining eastward to Lake Matapedia. A short distance beyond this small lake, the last rock cut in the dark "Cambrian" slates is passed and the railway enters a comparatively level area underlain by nearly flat-lying Silurian measures. The level area is bounded on the southwest by the high hills of the Shickshock or Notre Dame mountains visible from the railway. The Silurian strata unconformably overlie the "Cambrian". The lowest beds are white and pinkish sandstones with a thickness of about 60 feet (18 m.). These are overlain by dark grey fossiliferous limestone probably of Niagara age.

57·9 m. 93·2 km. **Sayabec Station**—Alt. 578 ft. (176·2 m.). Sayabec is situated about a mile south of the head of Lake Matapedia. A few miles past Sayabec the railroad approaches close to the shore of the lake. Nearly horizontal Silurian strata outcrop along the southwestern shores

Miles and Kilometres.

but on the opposite side, towards the head of the lake, folded "Cambrian" strata occur while towards the foot of the lake, metamorphosed rocks possibly of Pre-Cambrian age, are present.

Towards the foot of the lake and for the first few miles in the rather broad valley of Matapedia river, there are no rock exposures.

72·9 m. 115·7 km. **Amqui Station**—Alt. 532 ft. (162·1 m.). Beyond Amqui, rock cuts occur along the railway in dark slates with occasional beds of fine sandstone and thin beds of limestone. The measures in most places lie with low angles of dip but in places are highly inclined.

Approaching Causapscal the railroad crosses the river to the east side of the hitherto broad valley but which in this neighbourhood contracts.

86·3 m. 138·9 km. **Causapscal Station**—Alt. 454 ft.(138·4 m.). Beyond Causapscal, the river valley again broadens and cuts across a six-mile wide belt of greyish and yellowish sandstones and arenaceous shales. These measures represent the Gaspe sandstone series and are presumably of late Devonian age. The strata are highly inclined in the form of a synclinal fold. They terminate a few miles to the west of the river, while in an easterly direction they extend continuously for 150 miles (240 km.) to the extremity of Gaspe peninsula. At several places in the interior of Gaspe, the Devonian sandstone series rests unconformably upon Silurian measures. On the Matapedia, it was supposed by Logan, that the Silurian and Devonian were conformable.

92·8 m. 149·4 km. **Beau Rivage Station**—Alt. 366 ft.(111·6 m.). Beyond Beau Rivage, the Silurian area is again entered and numerous rock cuts in the highly inclined, dark grey calcareous slates occur along the railway to Matapedia Junction, where the Matapedia joins the Restigouche river.

Below Beau Rivage, the river valley gradually contracts and the bordering hills rise to higher heights. The various tributaries of the Matapedia river irrespective of their sizes, occupy

Miles and Kilometres. deep valleys joining the main valley at grade. The Matapedia valley also enters the wider, Restigouche valley at grade. The wide and deep Restigouche valley is the inland continuation of the broad valley of Chaleur bay.

120·9.m 194·6 km. **Matapedia Junction**—Alt. 53 ft. (16·2 m.).

DALHOUSIE AND THE GASPE PENINSULA.*

(John M. Clarke.)

INTRODUCTION.

The general region dealt with in the following account embraces the head of the Bay Chaleur region and the great peninsula of Gaspe. The Bay Chaleur is an east-west arm of the Gulf of St. Lawrence, about 100 miles (160 km.) in length, and constitutes the marine boundary between the provinces of New Brunswick on the south and Quebec on the north. It was discovered and named by Jacques Cartier in 1534. The chief affluent of the bay is the Restigouche river, in its lower reaches a continuation of the boundary line between the provinces and also the site of large private salmon-fishing preserves. The mouth of the Restigouche river and the head of the bay are conventionally located at Dalhousie, N. B., on the south and Maguasha Point, P.Q., on the north, and here the width of the bay is about 3 miles (5·4 km.). Campbellton lies on the Restigouche river, 15 miles (27 km.) above Dalhousie. Here the river has narrowed to about $\frac{3}{4}$ miles (1·3 km.). Opposite Campbellton on the north (Quebec) shore is the Reservation and Mission of the Micmac Indians at Restigouche.

The Devonian beds and their volcanic intrusives about Dalhousie were early discussed by Hind, Bailey and J. W. Dawson, and the official geological maps of the region were compiled by Ells, by whom also the geological relations of these rocks were discussed at some length. The first identification of the fossils was by Billings; subsequently the fossil corals were carefully studied by Lambe and more recently the entire marine Devonian fauna and stratigraphy has

*See Maps—Head of Chaleur Bay, and, Eastern Part of Gaspe.

been elaborated in detail by Clarke. The Devonian rocks at and near Campbellton are similarly intruded and altered by volcanics. They became of general interest through the discovery by Ells and Foord, some thirty years ago, of fish and plant remains, and it is to these fossils that geologic interest at this point has been chiefly directed.

The Gaspe Peninsula, bounded on the south by the Bay Chaleur, on the north by the St. Lawrence river, and fronting east on the Gulf of St. Lawrence, covers an area of about 11,000 square miles (28,600 sq. km.). It is larger than the Kingdom of Saxony and twice the size of the State of Massachusetts. The interior of this great peninsula is a rolling, heavily timbered wilderness, only the coast region, for a maximum width of 10 miles (18 km.), having been opened to settlement. Its geological structure is best exposed in the sea sections, some of which are very striking. The peninsula constitutes the northernmost and terminal region of the Appalachian Mountain system and here the folded ridges take on their most pronounced sigmoid curvature, bending from the SW.-NE. direction which is normal to them at the south, through an arc at the north which ends at Cape Gaspe in a NW.-SE. curve. Pertaining thus to the Appalachian system, the Gaspe region is quite exclusively an area of Palæozoic rocks. The Notre Dame or Shickshock* mountains, which are the greatest elevations of the peninsula, (3,000- 4000 feet or 900-1,200 m.), lie at the north and carry areas of mica schists, jaspilites and epidotised gneiss, evidently forming a basement to the Cambrian shales, but the Pre-Cambrian age of none of these has been demonstrated. Peridotites and serpentines are also of extensive occurrence in these mountains. Generally speaking, Gaspe is a region of regular appalachian folds and extensive overthrusts of the older Palæozoic strata, the extraordinary displacements in which have been largely concealed by a mantle of later (Devono-Carboniferous) nearly horizontal sandstones and conglomerates.

The geology of Gaspe was first studied by Sir William Logan in 1845. It was the first field he entered after his organization of the Geological Survey of Canada, and his reports upon the region are still fundamental. Later

* Notre Dame is Champlain's name for these mountains; Shickshock, the Micmac Indian name.

the region was entered by Bell, and particularly by Ells and Low, who made a resurvey of the peninsula in 1878-1882 and issued an entire series of maps of the area. Clarke has more recently studied the coastal region with special reference to the composition and correlations of its faunas and stratigraphy.

Along the shores of the peninsula are outcrops of the Cambro-Ordovician, Silurian, Devonian and Devono-Carboniferous (Bonaventure) formations. Not all of these formations have been deposited in one basin. The evidence is very clear that the earliest endroits were the broad marine channels of an ancient St. Lawrence trough having the SW.-NE. trend of the orogenic axes of to-day, with continental land at the north (the Labrador crystalline shield) and at the south, for the most part outside the boundaries of the present land. In some degree the bays of to-day (e.g. Gaspe bay, Mal bay) running in from the coast of the Gulf lie in ancient synclines which date back to the later stages of the Devonian. Sea erosion, however, has been so efficient that the lower reaches of the St. Lawrence river which washes the north shore of the peninsula are bounded by a wave cut rock platform in places 8 miles (14·4 km.) in width, lying at a depth of not more than 300 feet (90 m.) below the present water level. Where the sigmoid curve of the Appalachian ridges is most pronounced, that is, in the little peninsula of the Forillon at the north between the St. Lawrence river and Gaspe bay, the outermost eastern tip of the Appalachian system is to be found in the fishing ground known as the "American Bank", which, submerged a few fathoms, lies 10 miles (18 km.) out to sea from the tip of Cape Gaspe, in the SE. course of the mountain folds. This fact has been determined by the dredged rocks from this bank.

The course of the St. Lawrence river is believed to be determined by a deep thrust fault of the Palæozoics to the south against the crystalline Labrador shield to the north. This probability is more forcibly pronounced in the lower part of the river bounding the Gaspe shores than it is farther inland, for in Gaspe there is no single evidence that this river traverses the crystalline shield in such direction as to leave any part of the crystallines to the south. This highly significant directive fault line was long ago located by Sir William Logan and is commonly known as "Logan's fault". Along this fault plane and

against the crystalline horst behind it (north), the palæozoics have been shoved and overthrust, here as elsewhere throughout the 2,000 miles (3,600 km.) extent of the Appalachians, to the southwest, but here with the sharp crescentic curvature not elsewhere shown. The Island of Anticosti, which lies 60 miles (108 km.) east-northeast of Cape Gaspe, is an area of horizontal Silurian rocks outside the region of folding,—a *parma* lying between the horst and the Appalachian folds.

FOLDS.

From the St. Lawrence river shore southward to Percé the folds of the strata are exposed and certain fairly definite anticlinal courses across them were determined by Logan and in large measure confirmed by later observers. These are apparently five in number, beginning at the north:

1. Forillon anticline (overthrust);

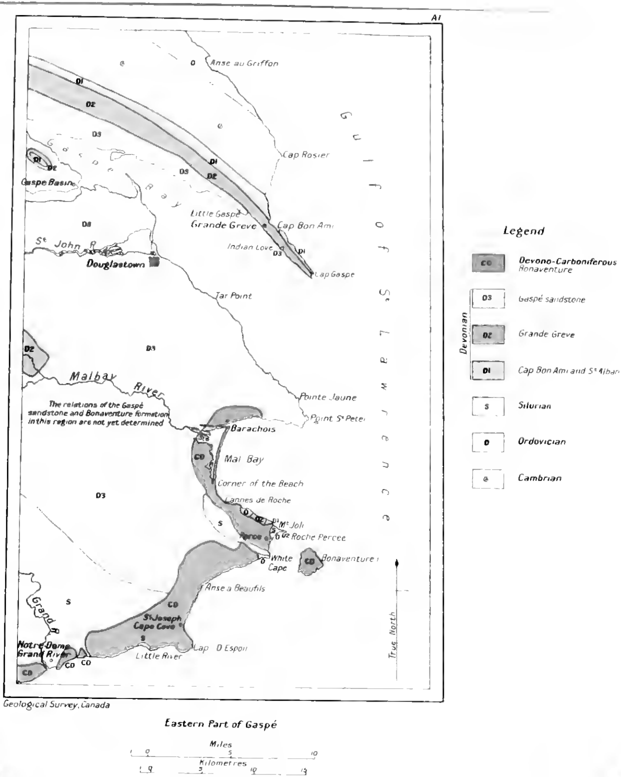
2. Haldimand anticline; the axis runs through Gaspe mountain (Gaspe basin) and enters the bay at Cape Haldimand. In the trough between folds 1 and 2 lie the upper reaches of Gaspe bay and the lower course of the Dartmouth river or Nor'west arm.

3. Tar Point anticline; strikes the bay at Tar point on the south shore of Gaspe bay. Between it and fold 2 lies the barachois at Douglastown and the lower course of the St. John river which flows into it.

4. St. Peter anticline, meeting the sea at Point St. Peter.

5. Percé anticline. This is by far the steepest and most extensive of all the folds and is badly broken down at its sea end. Between it and fold 4 lies Mal Bay, its barachois and river. South of Percé the folds have been obscured by the mantle of the overlying Bonaventure formation (Devono-Carboniferous) which is feebly folded at the north end but this folding is of a much later date than the fundamental folds. This covering of red rock is spread over the south and southeastern parts of the peninsula and lies everywhere on the almost vertical edges of the great series of Ordovician-Silurian (mostly the latter) light gray and blue limestones.

A1.



Geological Survey, Canada

Eastern Part of Gaspé

ORDER OF SUCCESSION.

In proper order of succession, the earliest rocks are exposed on the St. Lawrence river shore in a narrow belt of black Cambrian or Cambro-Ordovician shale to be seen at Cap Rosiers and thence up the river (*Rosiers shale*). Following immediately south (see map for position and direction of these belts) rise the steep cliffs of Lower Devonian (*St. Alban*, *Bon Ami* and *Grande Grève* beds). In the ascent from the low wave cut plateau of Cap Rosiers to the heights of the Bon Ami cliffs, one traverses the thrust plane between the Rosiers shale beds and the St. Alban lime shales, along which most of the Ordovician and all the Silurian to an unknown thickness has been squeezed out.*

This is the *Forillon fold*, the southern flank of the Cap Rosiers overthrust. In it the Devonian St. Alban, Bon Ami and Grande Grève beds, all conformable, are inclined quite uniformly west of south at angles of 25°-30°, but the Cambro-Ordovician Rosiers shales on which they lie are almost vertical and always highly distorted. It is not now possible to estimate the degree of this overthrust or extent of the Devonian cover but it would seem to have at least extended 8 miles (14·4 km.) seaward to the 50 fathom line. If the Silurian has actually been squeezed out by the overthrust it is probable that a formation of very great thickness has thus disappeared from the succession, for at the Black Capes on the Bay Chaleur shore, the Silurian, in the most complete Silurian section yet known in the Gaspé peninsula, is upward of 7,000 feet (2198 m.) in thickness.

The St. Alban and Bon Ami beds are sparsely fossiliferous, but the conformable Grande Grève beds of purer limestone are highly abundant in species typical of the earliest Devonian limestone beds, Helderberg and Oriskany At the north neither of these formations is anywhere well exposed except on the little Forillon peninsula though both extend inward (west) into the timbered heights of the northern mountain ridges.

Two remote and detached masses of this early Devonian limestone at Percé, 15 miles (27 km.) due south from the

* There is an alternative reason to believe that the Silurian is absent at the north by extinction of the deposition, but this construction of the section would only lessen the amount and not the mode of destruction by the overthrust.

Forillon, constitute the most brilliant and striking scenic features of the Gulf coast: 1. Percé Rock (*Le rocher percé; L'isle percée*), 2. Les Murailles. These limestone masses carry a smaller fauna, in some measure distinct from that of the Grande Grève beds, but their identity of age is unquestioned. Further special reference is made in the proper place to them and to the Ordovician and Silurian cliffs of Percé.

Next south and overlapping unconformably the Devonian limestones of Grande Grève is the broad band of *Gaspe sandstone*; so named by Logan. This is a heavy mass of red, brown and grey sandstone with many coarse pebble layers. Contact of the basal beds with the limestones is to be seen on the Forillon peninsula at Little Gaspe and at several places from Grande Grève out to Cape Gaspe there are infaulted masses of the sandstone in the limestone beds, which indicate that the coating of sandstone has been stripped from the latter. Cliffs of Gaspe sandstone are exposed on all the south shore of Gaspe bay, at Chien Blanc, Point St. Peter (the south cape of the bay) and thence into the north shore of the Mal bay where their identity is gradually lost by conformity in composition to the overlying Bonaventure conglomerate. From measurements of the shore sections supplemented by traverses of the great expansion of these sandstones in the interior, Logan inferred a total thickness of more than 7,000 feet (2,198 m.). Ells has rightly believed this figure too high on account of faulting, but the amount of duplication from the displacement and the actual lines of faulting have been difficult to decipher on account of the homogeneity of the strata. The Gaspe sandstones contain an abundance of terrestrial plants which have been described by J. W. Dawson and indicate middle Devonian affinities. The marine fauna of the sandstone is profuse at certain low levels in the series and these species are characteristic survivors of the Grande Grève fauna with an addition of species of later Devonian date, identical in large part with the Hamilton (middle Devonian) species of New York.*

*Of these fossiliferous localities of the Gaspe sandstone, it may here be stated that those which have been most carefully studied lie at the rear (west) of the first hill behind Gaspe Basin at the head of Gaspe bay and thence north to L'Anse-aux-cousins and Pointe Naveau on the Dartmouth river; at Friday's bluff on the St. John river about 30 miles (50 km.) west from Douglastown and along the courses of the Mississippi and other brooks tributary to the York river, about 35 miles (63 km.) in from the coast.

The Bonaventure formation. Beginning with the south shore of Mal bay, is a great mantle of red conglomerates and sandstones which covers all the coast regions from here south over the whole Bay Chaleur region, save where it has been torn away by sea and weather and left the underlying formations exposed. The name Bonaventure was given by Logan and was taken from Bonaventure island off the coast of Percé which is entirely constituted of these conglomerates though they rise to greater heights in Mt. Ste. Anne at Percé (1,200 feet). The formation is almost horizontal throughout its extent, but the gentle undulations of its northern portion are admirably expressed in the broad rolling summit of Mt. Ste. Anne. This Bonaventure formation is in part of distinctly continental origin but its heavy conglomerates have doubtless been piled together along a rough coast not unlike that which now faces the Gulf. These conglomerates are in considerable measure composed of blocks and boulders of the fossiliferous rocks beneath, Cambrian to Devonian, and they are frequently of enormous size, having in one instance a weight of 8 tons, the angularity of this fragment indicating that it had fallen from an overhanging sea cliff. The Bonaventure formation is believed to represent the later stages of the Devonian and the early stage of Carboniferous time, indeed all of the latter that is recorded by deposits on the peninsula. It is also the youngest rock formation in Gaspe. By the early observers it was considered as altogether of Carboniferous age and was correlated with the red sandstones of Nova Scotia, Prince Edward Island and the Magdalen islands which are now known to be of Permian age. Ells was the first to recognize a distinction in the composition of the conglomerates and thereupon based a distinction in age, calling the lower or limestone conglomerates, Devonian, and the upper beds with fewer lime and more crystalline pebbles, Carboniferous, a difference not easy to recognize at many localities.

The limestone conglomerates at the base are clearly exposed at and about Percé, and the upper beds in the summits of Percé mountain. In the outcrops on the Bay Chaleur shore, this distinction is much obscured and the red sandstones and conglomerates with jasper pebbles lie everywhere on the upturned edges of the grey Silurians often producing brilliant colour contrasts. The total original thickness of these Bonaventure beds is not known.

In Mt. Ste. Anne, Percé, they stand at 1,200 feet (370 m.) and in the Carleton mountains at Carleton, Bay Chaleur, at nearly the same height. They contain no contemporary animal remains so far as known, but plant remains, as yet undetermined, and even thin coal layers, have been found in the fine sandstones of Cannes-des-Roches on Mal bay.

PALEOGEOGRAPHY.

The ancient geography of this region has already been intimated. In Cambrian, Ordovician and Silurian stages the sea way or channel, bounded by the old land at the north and south, was broad and uncomplicated, forming an open passage from the north transatlantic strand into the waters of the Appalachian interior. During Silurian time especially, this passage following the Appalachian synclinal was nearly as broad as the Gaspe peninsula and we have as yet no evidence that it was greatly obstructed. So far as known its faunas, as well as those of the Ordovician bear a decided Atlantic (transatlantic) aspect. The upfolding of these strata constructed new and narrow channels at the opening of the Devonian, but these were clear and the faunal correspondence between them and contemporary deposits of the interior is very close.

Regarding these Devonian channels it may be said:—

(1) There was a definite and open passage from Gaspe into New York and the southern Appalachians during the period of the earliest Devonian (Helderbergian) when a well defined element of the Helderberg fauna flourished in the St. Alban beds.

(2) A similar open way existed at approximately or actually the same time, connecting the Dalhousie beds of northern New Brunswick with the Helderbergian of the interior.

(3) These two passages seem to have converged and united toward the west and south, for while each carries a clear predominance of Helderberg species the two have comparatively little in common.

(4) In the later stage represented by the Grande Grève limestones the northern passage became broadened while the Dalhousie channel became extinct. In addition to these open passages from the interior outward were others of Devonian date further south, and the relations of these sea ways have been discussed by Clarke (**11**, p. 153-162.).

5) The Gaspe sandstones indicate a general breaking down of the barriers of the northern channel which permitted a later (lower or middle) Devonian invasion of species from the interior, while the Grande Grève fauna still persisted. Flood and barachois conditions governed the early deposition of these sandstones but encroaching elevation eventually changed the middle and later Devonian conditions to those of a rias coast not unlike that of the present.

THE ORIGIN OF THE GULF OF ST. LAWRENCE.

The hydrographic charts of the Gulf indicate very clearly that the course of the ancient St. Lawrence river was from its present mouth southeast, far to the east of Gaspe, east of the Magdalen islands, and thence outward to the Atlantic by the passage between Cape Breton island on the west and Newfoundland on the east (Cabot strait). The St. Lawrence river is a very ancient waterway and takes its date from at least as early as the time of the marine (Lévis) channel of the early Ordovician, a passageway which led from Atlantic waters into the Appalachian gulf of the interior of the continent. Fixity was given to this waterway by the long subsequent faulting of the Palæozoic rocks against the crystalline Labrador shield at the north, and ever since this factor became efficient the passage has been now and again a salt-water channel and a fresh-water drainage way. That part of the river channel now submerged beneath the Gulf waters is not the oldest portion but a later part of the river, where the valley was cut out through marine rocks which had been deposited over the bed of the Gulf when that was open ocean.

The orogenic axes of Appalachian disturbance through the Gulf region are twofold: that at the south, passing through Nova Scotia and on into Newfoundland keeping a N.E.-S.W. trend without change of direction; that at the

north, passing through Gaspe, curving at its termination in an arc, convex northward: thus:

Orogenic Appalachian axes. Gulf of St. Lawrence.

The torsion of the northern fold, ascribable to the resistance of the Labrador shield, produced a syntaxis which broke down that fold and dislocated the bottom of the Gulf area in a line continuous in direction with the course of the fold. Thus with the fracture of the pavement of the region and the consequent differential elevations and depressions, the St. Lawrence waters took somewhat the course now indicated by the hydrographic chart; probably for a part of the time or by way of a subsidiary channel taking the passage out by the Strait of Belle Isle and bending about Anticosti island to the north and east. This was thus a secondary condition of the river, dating to a time subsequent to the uplift of the folded Palæozoic rocks. Since that time, the broken down Gulf region has successively been a river way, an open marine body, an estuarine basin, and again a more or less enclosed sea. After the recoil of the northern fold which broke down the regularity of the mountain building and left the parma of horizontal rocks at the north (Anticosti island), came a period of rough rias coast along the broken ends of the Appalachian folds with a sea which received the mantle of Bonaventure conglomerate, when the marine waters had a far wider westward extent than to-day and the river channel south of the latitude of Percé was deeply buried. This period was followed by a shallowing of the basin which brought on the estuarine conditions of the coal period, with occasional irruptions of marine conditions; then a still farther elevation of the gulf bottom, which

resulted in broad coastal sand plains under comparatively arid climate, during which the red Permian sands of Nova Scotia, Prince Edward Island and the Magdalens, with their sand-etched boulders, were laid down. With the close of the Palæozoic the lower channel of the river across the Gulf region was high, the rock land on the west and east extended close to it so that the channel now buried in the Gulf was then the efficient river channel. The cutting down of the land into its present broken coast line and scattered islands and the submergence of the river channel have taken place since the opening of Mesozoic time.

GLACIAL AND POST-GLACIAL PHENOMENA.

Gaspe does not appear to have been within the reach of the great continental ice sheet. Its glacial phenomena are scattered and evince only movements of land ice downward from the mountains of its interior and deposits of this origin are everywhere complicated with sea ice transportation; thus every northern boulder is under suspicion of having been brought in by floating ice. The islands off the coast, Prince Edward Island and the Magdalens, are unglaciated.

Elevated beaches are to be found at various points on the peninsula. These are widely scattered and show evidence of Pleistocene warping as in the case of the terraces exposed at Gaspe basin.

DETAILED DESCRIPTION.

Percé.*

L'Anse-au-Beaufils, the station for Percé, lies on the coast 5 miles (9 km.) to the south.

From L'Anse-au-Beaufils, Bonaventure island, from which Bonaventure formation takes its name, is seen at the east and the Percé mountains at the north. The road to Percé leads from here due north and crosses Cap Blanc or Whitehead.

View of Percé from the Summit of the Road over Cap Blanc.—The village (shire-town of Gaspe county) is on a triangular rock plateau, with Mount Joli at its apex,

*See Maps—Percé and vicinity, and, Percé.

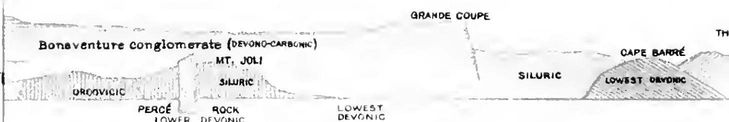
facing the Percé Rock; Bonaventure island 2 miles (3·6 km.) long, 3 miles (5·4 km.) out to sea; at the left Mount Ste. Anne 1,200 feet (370 m.) A. T.; on the further side of the triangle the ragged sea cliffs (Les Murailles), which front on Mal bay; the north side of Mal bay is formed by Point St. Peter with Plateau island and on the distant horizon at the right is Cape Gaspe (Shiphead). Beyond is the St. Lawrence river.

Percé Rock.—This noteworthy insulated cliff, anciently the *Isle percée*, early in the history of the settlement gave its name to the mainland. L'Isle percée, le rocher percé, Pierced rock, Split rock or Percé rock, as it is variously termed, is 2,100 feet (646 m.) long from prow to the outer end of the rear obelisk, 300 feet (91. m.) wide in its greatest breadth and 288 feet (87 m.) high at its prow. The arch through it is 60 feet (20 m.) high. In plan its form is somewhat angular or zigzag and viewed from in front resembles a giant steamer coming into port.

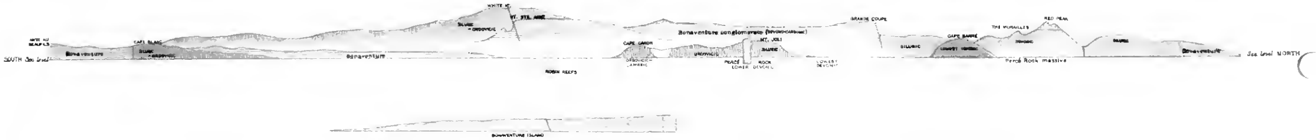
The rear obelisk is the outer flank of a second arch which fell in 1845. Back in the early 1600's there seem to have been two other arches toward the seaward and thinner end, and the wastage of the rock has been effected within recorded time largely by the downbreaking of these arches. There is still another arch in the rock, transecting the obelisk parallel to the major axis of the mass. The wastage of Percé Rock under the impact of the waves is very slight. Freezing and thawing are more efficient agents but during the past ten years not enough has fallen from all these causes combined to alter the outline of the cliff in any perceptible degree and the line of the prow has not materially changed in 150 years. At high tide the Rock is isolated, but at low tide a batture or sandbar extends to it from the foot of Mount Joli affording ready access to the point and south side of the cliff. The north side is accessible only by boat. The sheer sides of the Rock make attempts to scale it exceedingly perilous and such attempts are now forbidden by municipal ordinance.

Fossils abound in these strata, distributed in thin layers with barren interspaces. They correspond in characters and association with the richer fauna of the Grande Grève limestones, and the Percé Rock massive is correlated with that formation (see p. 90). Forty-four species have been described, of which 31 occur in the Grande Grève

SEA FRONT AT PERCÉ



PANORAMA SKETCH OF THE SEA FRONT AT PERCÉ



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Panorama of Percé from the south

beds. Characteristic species are *Dalmanites (Probolium) biardi*, *D. perceensis*, *Phacpos logani*, *Chonetes canadensis*, *Chonostrophia complanata*, *Spirifer arenosus*, *S. murchisoni*, *Leptocœlia flabellites*, *Rensselaeria ovcides*.

No other trace of the formation and fauna represented by Percé Rock is to be found in this vicinity except in the *Murailles* or sea cliffs which lie beyond the North Beach and face the Mal bay. The grey headland of Cape Barré with which the Murailles begin, is followed by a faulted and overthrust mass of highly coloured strata, dipping S.E. 20° and abutting against the Cape Barré strata, containing, sparsely, the fossils of the Percé Rock strata. These inclined strata rise to the high peaks of the Murailles but their tops are there coated unconformably by a layer of the limestone conglomerate of the Bonaventure series.

The observer will not fail to notice the colony of waterfowl nesting on the green capped top of the *Isle perce*. This settlement is composed only of the Herring gull (*Larus argentatus*) and the Cormorant (*Phalacrccorax carbo*), an association which is repeated on the cliffs of the Forillon peninsula 17 miles (30 km.) to the north (see note beyond on the bird colony of Bonaventure island).

Percé Rock is composed entirely of Lower Devonian limestones standing nearly vertical (dip 80° S.E.) and highly tinted with iron yellows, reds and purples. Its strata are seamed with calcite veins of white, red and deep brown, often with interesting crystallizations. The combination of rock colours with the green cap of verdure produces striking effects which vary with every change in atmospheric conditions and the position of the sun.*

Cape Barré.—This is the southern point of the Murailles, bounding the North Beach. Its strata are thin, sandy, blue grey shale and limestones dipping 30°-40° N.E., the red rocks of the Percé massive being faulted against them. These rocks contain only a few fossils, all of Lower Devonian type (*Spirifer* cf. *modestus*, *Leptostrophia oriskania*, *Conularia* cf. *lata*), the most significant being a species of the trilobite Dicranurus (*D. limenarcha*) of which only two other species are known, both from the

*For an account of the history of Percé Rock in the records of Gaspe, of its changes in form, rate of degradation, total fossil contents, etc., see Clarke [9].

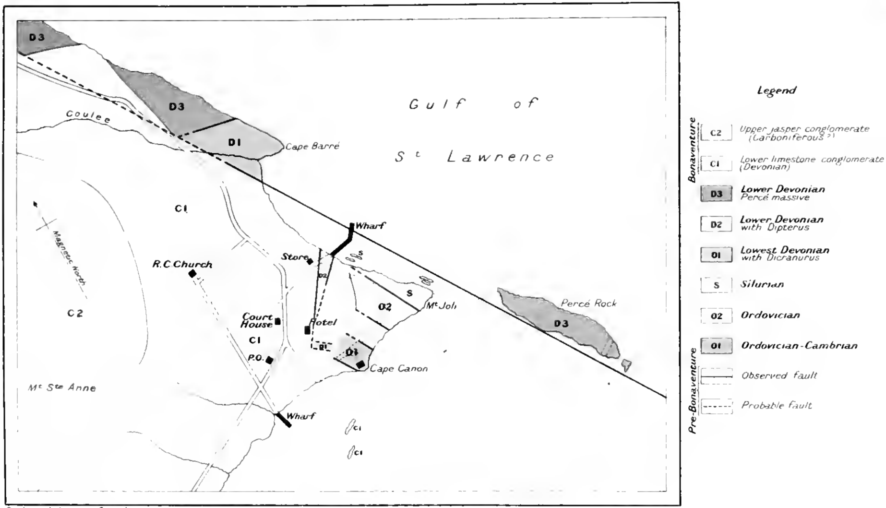
Lower Devonian, one of Bohemia and the other of New York.

These beds are not distinctly developed elsewhere in the region and they appear to represent a Devonian stage earlier than that of the Percé Rock.

The Rock Wall between the North and South Beaches.—Just at the steamboat wharf on the North Beach recent excavations, now covered, exposed a grey, steeply inclined shale carrying *Dipterus*. No other fossil has yet been determined from this shale which is regarded as belonging to a Devonian stage beneath that of the Percé massive. This shale is apparently faulted against the Silurian at the south and limited at the north by the fault lines of the beach. Following the shore southward the first outcrop is of the erect grey limestones and shales of Mount Joli. The rock exposures begin with the reefs exposed at low water to about 400 feet from the shore and the Mount Joli cliff as a whole has a sea front of about 700 feet (211 m.) and the same dip as the Percé Rock strata. This would give the formation here an approximate total of 1,100 feet (335 m.). There is little change throughout in its lithic characters, but there is clear evidence of a displacement within the mass which gives a geological meaning to the division of the massive into a *north flank* and a *south flank*. The beds of the north flank afford admirable exhibitions of jointing and ripple marks and in both flanks fossils are to be found in thin beds with barren intervals. In the north flank are the corals *Duncanella*, *Zaphrentis*, *Streptelasma* and *Pleurodictyum*, the graptolite *Monograptus* cf. *clintonensis*, the brachiopods *Dalmanella*, *Leptæna* (*rhomboidalis*), *Stropheodonta*, *Spirifer* (cf. *niagarensis*, *modestus*) and an uncertain *Phacops*: all of which indicate a Silurian stage.

In the south flank of Mount Joli are the trilobites *Ampyx*, *Tretaspis*, *Calymmene*, *Trinucleus*, *Pterygometopus*, *Ptychopyge* and *Illænus*, the brachipods *Dalmanella*, *Rafinesquina*, *Strophomena*, *Parastrophia*, *Zygospira*, the assemblage indicating a middle or later Lower Ordovician stage. These beds seem to extend across the mountain and just touch the other shore near the wharf house.

This exposure ends abruptly at the south in a short beach covering a fault, beyond which is *Cap-du-Canon*, a mass of erect, dark argillaceous and calcareous slates, much crumpled and glazed. The general inclination



Geological Survey, Canada

Percé, Gaspé

Feet
1000 500 0 1000 2000
Metres
0 250 500 1000
(Scale of map is approximate)

of the bedding is not different from that of the Mount Joli massive, but the beach interval, continued over the surface of the ground as a swampy depression, is indicative of their discontinuity.

Not far landward of this cliff is an isolated boss of limestone conglomerate which is apparently a part of the same mass, though its much more massive calcareous character indicates a part not there represented and possibly cut off from that by a displacement. No fossils have been with certainty derived from these rocks,* but their age is probably Ordovician or Ordovician-Cambrian.

The Cap-au-Canon can be passed only at a low stage of the tide, and with it the rock section ends at the South Beach.

Mount Ste. Anne.—This mountain (1,200 feet, 370 m.) rises just behind the village, exposing toward the sea its upper precipitous face of red conglomerates. A grassy road leads up to the mountain on the north side, but on nearly all other sides the mountain faces are vertical fault walls. The view from the summit is fine with clear weather, affording a panorama of the coast, its capes and islands, from the St. Lawrence river at the north to the Bay Chaleur at the south, and of the rolling wilderness of the hinterland. Ste. Anne is the foremost of a mountain cluster known as the Percé mountains and is the only member of it that is composed of the *Bonaventure conglomerate*. The ascent of the mountain shows limestone conglomerates in the lower part and jasper conglomerates above. The attitude of these beds approaches the horizontal at the south, but is undulating and dips gently down toward the north. The mass everywhere sheets the upturned broken and eroded edges of the vertical Ordovician-Lower Devonian cliffs, and it here reaches its northernmost limit in recognizable expression. At more northern points a distinction between these conglomerates and the Gaspe sandstones is obscure but there are reasons to believe that the upper sands and conglomerates on the south shore of Gaspe bay, which have been included in the Gaspe sandstones, pass without much change of attitude into the Bonaventure formation.

* The limestone boss was formerly a place for lime burning, but the limestone for this purpose was brought from Cap Blanc and the Ordovician fossils that have been referred to this outcrop may have come from the more distant locality.

The mass of Mount Ste. Anne is peculiarly isolated by a series of fault scarps one of which fronts the sea at the east; a second, the Grand Coupe, faces the north; and a third, the Amphitheatre, lies behind the mountain facing the southwest and separates the mountain mass from the zone of Silurian limestones which almost encircles it.

The throw of these faults is indicated by the fact that the exposed beds of conglomerate seen in the coast ledges south of the South Beach and thence on southward to Cap Blanc are mostly of the middle and upper beds carrying jasper pebbles with a few fossil-bearing limestone and slate pebbles. These intimate a displacement of approximately 1,000 feet (300 m.). (See under Cap Blanc).

Cap Blanc or Whitehead is the sea-end of the southern rock ridge bounding the Percé triangle. It is a mass of light grey Ordovician limestones, having the steep dip (80° SE.) of all Palæozoic strata here lying beneath the Bonaventure formation. In approaching the cape from the north these limestones are seen to rise gradually from the sea, and are overlain by the slightly inclined basal beds of the Bonaventure conglomerate. The entire series of the lower beds is overturned, the Ordovician lying above the Silurian. The first or northernmost of these are latest in age and they alone in the series are tinted red and greenish, but soon pass into grey. Probably some part of the red stain in these beds has been derived from the red Bonaventure over them. The overlapping beds soon disappear leaving the erect strata standing alone and giving name to Cap Blanc which is conspicuously white by contrast to the red rocks about it. Just beyond the point of the cape these grey limestones are cut off and terminated by a sharp fault against the Bonaventure beds, the former having moved down, as shown by the down-dragged edges of the Bonaventure. Access to the cliff for purposes of examining the rocks is difficult except at low tide in a gentle sea.

The lower and later red-greenish beds contain some fossils in abundance: *Favosites* (cf. *hisingeri*), *Halysites catenularius typicus*, *Lyellia*, *Callopora*, *Cladopora*, *Lichas*, *Chonetes* (type of *novascotica*), *Catazyga* or *Zygospira*: enough to indicate a Silurian age, though most of the species have not been determined. The grey beds farther south are sparsely fossiliferous but carry an Ordovician fauna as early as the Trenton and comparable to that of

Mount Joli-south flank:—*Phacops primævus*, *Calymmene senaria*, *Ceraurus pleurexanthemas*, *Camarospira bisulcata*, *Zygospira recurvirostra*, *Bolboporites*, etc.

The total thickness of these limestones approximates 1,000 feet (300 m.) and there is no evident displacement within the mass. Their relations otherwise conform closely to the beds of like age in the Mount Joli section, though there is no noticeable degree of identity in the species of fossils which occur in the two sections.

Bonaventure Island—This island, 2 miles (3·6 km.) long, 1½ miles (2·7 km.) wide and 3 miles (5·4 km.) out to sea, is separated from the mainland by a channel in which the tidal currents run heavy. The island is an ancient fishing site dating back to the days of the 16th and early 17th centuries when Basques, Bretons and the men of La Manche came out every year for the fishing, returning to France in time for the lenten market. The rocks of the island are entirely of the Bonaventure conglomerate and represent the upper beds, the basal limestone conglomerate not being present. It is thus, in the present interpretation of the formation, a mass of Carboniferous rocks. The island presents a low face on the channel side but the cliffs on the east rise to 400 feet (120 m.) making a noteworthy fault face. These cliffs have an added interest because of the large colony of water birds which nest here. The assemblage is not surpassed in size anywhere in the Gulf except on the celebrated Bird Rocks of the Magdalen islands which politically belong to Gaspe but lie 160 miles (288 km.) out to sea. The species nesting here are the gannet (*Sula bassana*), Kittiwake (*Rissa tridactyla tridactyla*), Brünnich Murre (*Uria lomvia lomvia*), Puffin (*Fratercula artica artica*), Razor-billed Auk (*Alca torda*) and perhaps one or two more—an association entirely like that on the Bird Rocks. In these Gaspe waters there are two bird assemblages of this kind and two other associations which consist only of the Herring Gull and the Cormorant. It is a curious coincidence that the former and larger assemblages, alike in kind, nest only on the horizontal ledges of Carboniferous sandstones while the lesser combination breeds only on the inclined strata of the Lower Devonian limestones.

The Girdle of Ordovician-Silurian from Cap Blanc (south) to Corner-of-the-Beach (north).—From Cap Blanc this heavy mass of overtipped limestones passes inland, bounding the

south flank of Mt. Ste. Anne, then passing behind that mountain, rising to greater heights and forming the broken range known as White mountain, which almost encircles and isolates Mt. Ste. Anne, approaching sea level at Corner-of-the-Beach on Mal bay. A fault-bounded outlier of this rock may be seen in a white cliff on the sea front beyond the Murailles, where it lies at an angle against the Bonaventure beds beyond. Much remains to be learned of the fauna of this extensive belt of limestones.

GEOLOGICAL RELATIONS.

The foregoing account of the leading topographical and geological features has intimated the geological history of Percé. The steeply tilted older strata present the seaward end of an Appalachian fold of great magnitude, which has been variously broken down. The uniformity of the inclination in the steep fold is expressed by the coincident dip of all the older beds, 80°-85°SE., and this fold, steeply inclined to the north, involves beds from (Cambrian) Lower Ordovician into upper Lower Devonian.

The construction of the tectonic changes here is complicated, perhaps not altogether clear, but the secondary movements expressed by dislocations of the strata are of two orders in time. Of the older faultings there are unlike orders in magnitude. The great Percé fold, exposed only at its sea edge, may be construed as typically Appalachian in its thrust northward. It was an earlier fold than those to the north of it, and was not thrust against a horst of crystallines. The over-tipped Silurian and Ordovician strata present in the Mount Joli section and repeated 2 miles south at Cap Blanc, indicate a profound displacement along the thrust plane after folding which carried southward the inverted succession of the strata; a displacement which would involve the conception of gravitational movement backward (south) along the plane of thrust; a conception apparently reasonable, and squaring with carefully repeated tests. The lesser displacements involved in the down-breaking of the Percé fold are indicated on the accompanying map in which those of earlier age are marked by single lines, and those visibly affecting the Bonaventure formation only, by double lines, in both instances dotted where the break is uncertain. Percé Rock is evidently bounded on its long sides by faults which have isolated

it wholly and cut out from beneath it the earlier Devonian stage represented by the rocks of Cape Barré and the wharf-foot. This cut-off mass of Devonian extending along the face of the Murailles has itself been faulted across, as indicated.

The beach depressions both north and south are undoubted displacement areas, the first being the interval between the Devonian of the Murailles and the Silurian of Mt. Joli (North Beach); the second or broad South Beach being the area of general breaking down of the great arch.

The displacements which took place at a later date than those mentioned have visibly affected only the Bonaventure conglomerate. These may be thus enumerated: (1) The seaward scarp of Mt. Ste. Anne. Bonaventure island seems to be the downthrown mass from this displacement, the "Robin reefs" lying off the South Beach remnants of the same mass; (2) The strata of Bonaventure island dip slightly to the S.W. and the sheer cliffs of the northeast front are a fault face. At the foot of these cliffs the bottom drops immediately to 30 fathoms; (3) The Grand Coupe at the north; (4) The Amphitheatre at the back of Mt. Ste. Anne.

Relative Thickness of the Older Palæozoics at Percé.

Devonian	Percé beds in Percé Rock 250–300 feet but probably rising in Les Murailles to......................	500 ft. (153 m.)
	Cape Barré Beds...........	100 ft. (33 m.)
Siluro-Ordovician	Mt. Joli massive...................	1,100 ft. (339 m.)
	Cap-au-Canon massive.............	600 ft. (200 m.)
		2,300 ft. (725 m.)

The thickness of the strata at Cap Blanc which are doubtless a repetition of part of the foregoing beds, is 800–1000 feet (303 m.). The estimated thickness then of the pre-Bonaventure beds at Percé [Lower Devonian-Ordovician (Cambrian?)] is about 2,000 feet (606 m.), without making allowance for loss by faulting.

GASPE.

The terminus of the railway is at York on the south side of Gaspe Basin, passing an instructive cut through the Gaspe sandstones (Middle Devonian). These are however not the lower beds with marine fossils, but the plant-bearing strata which at this point probably lie above the marine beds. Crossing by ferry to the Gaspe side, the Gaspe sandstones may be seen near the landing dipping at a steep angle to the north. Gaspe bay lies in a synclinal of the sandstones, that is, in an ancient Appalachian trough the other arm of which constitutes the hill slopes on the north side of the bay where the dip is to the south. The marine fossils occur for the most part in strata behind the Gaspe mountain and up the Dartmouth river (at the north), distances of 3 to 4 miles from Gaspe Basin. The fossils are Middle Devonian species of the interior or New York sea commingled with more or less local Lower Devonian types which have survived from the period of the Grand Greve fauna.

GRAND GRÈVE AND THE FORILLON.*

Grande Grève, 14 miles (22·5 km.) distant by water from Gaspe, is a little fishing settlement on the peninsula of the Forillon. This Forillon peninsula bounds the north side of Gaspe bay and lies between that bay and the St. Lawrence river. At its upper end and near the head of the bay it has a width of 20 (32 km.) or more miles, but at Grande Greve and thence to the Cape, a distance of 4 miles (6·4 km.), its width does not exceed $\frac{1}{2}$ mile (0·8 km.). As elsewhere observed, this part of the Forillon is a single Appalachian ridge sliced vertically in half along its axis, its end at Cape Gaspe making the easternmost seaward face of the Appalachian system. From Grande Grève westward the ridges are multiplied in number by the accession of the slate cliffs at the north, but from Grande Grève east the half ridge alone remains, though furrowed on its surface by a coulée which gives the cape a double head; the northern, Cape Gaspe; the southern, Shiphead.

Only the south flank of this ridge remains and the dip of the strata—almost coincident with that of the hills—is toward the south, while their cut-off edges form the high cliffs which face the St. Lawrence river.

*See Map.—The Forillon, Gaspe.

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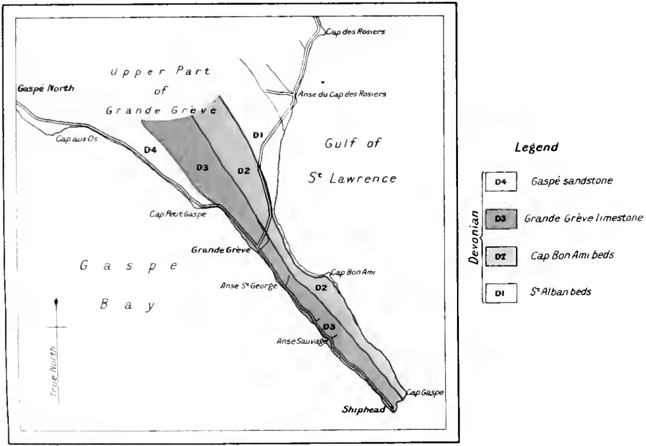

Geological Survey Canada

The Forillon, Gaspé

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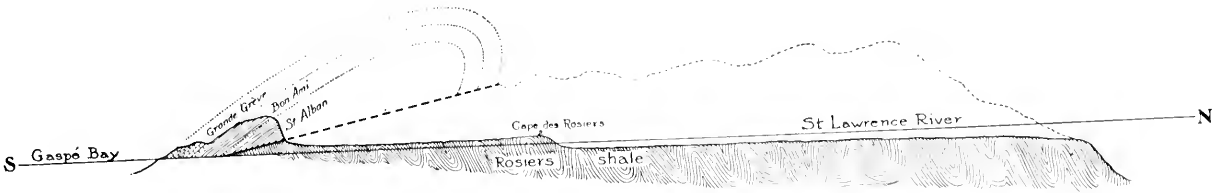

North-south section across the Forillon peninsula, Grande Grève to Cape des Rosiers, showing the overthrust of the Lower Devonian on the Ordovician-Cambrian.

We have here to deal with a heavy series of early Devonian limestones and lime shales unconformable to and overthrust upon the Cambro-Ordovician slates exposed at the north. The upper limestones, facing the south, are exceedingly rich in fossils, but the exposures are for the most part to be found on the little crescentic fishing beaches where the sea has cut out joint blocks of the strata. The thrust plane or base of the Devonian series has not yet been observed though further exploration may reveal it at the north base of the sea cliffs.

Starting from Grande Grève beach the section of the rocks is approached in reversed order, from top to bottom. Here and along all the neighboring beaches the upper strata of fossil-bearing Grande Grève limestones are exposed and actual unconformable contact of the uppermost beds with the red plant-bearing Gaspe sandstone is to be seen at Little Gaspe $1\frac{1}{2}$ miles (2·4 km.) westward on the shore. The division of the total limestone series (St. Alban, Bon Ami and Grande Grève) is as yet a broad one based upon lithologic and faunal rather than diastrophic characters. The upper member of this series or Grande Grève limestone is also divisible on the basis of its fuana, into distinctive early and late elements, but taken as a whole the species of the Grande Grève member are eminently characteristic of the Helderberg-Oriskany with a considerable representation suggestive of incipient stages of the later Onondaga fauna of the New York standard. A total fauna of 155 species has been described from the Grande Grève limestone and a visitor may expect to find in the upper beds characteristic species of the trilobites *Phacops* (*logani*, *gaspensis*), *Dalmanites* (*phacoptyx*, *dolbeli*, *emarginatus*, etc.), *Probolium*, *Cordania*, *Lichas* and *Gaspelichas*; the cephalopods, *Kionoceras* and *Orthoceras*; the pteropods *Hyolithus* and *Conularia*; abundant gastropods of the genera *Platyceras*, *Eotomaria* and *Diaphorostoma*; the pelecypods *Pterinea*, *Megambonia*, *Palaeopinna*, etc.; a large array of brachiopods, *Spirifer arenosus*, *murchisoni* and many more, *Rhipidomella logani*, *Stropheodontas* and *Leptostrophias*, *Leptocoelia flabellites*, *Nucleospira*, *Rensselæria ovoides gaspensis*, *Megalanteris*, etc., etc. A very notable percentage of these species have a wide geographical rang and the affiliation of the fauna is distinctly American

The lower beds of the Grande Grève division are exposed on the Kings road and carry an association of species which is most distinctively indicative of the Oriskany horizon; such as *Hipparionyx proximus, Rensselaeria ovoides gaspensis, Spirifer arenosus, Chonostrophia complanata, Rhipidomella musculosa*, etc. The limestones carry much nodular chert and in some places masses of silicious sponge spicules constitute the basis of the rock.*

Beneath the Grande Grève limestone lies a series of less purely calcareous, more magnesian beds, with but few fossils and these mostly diminutive forms,—a deposit formed under impeded marine conditions in which life was unable to flourish. These are the *Bon Ami beds*, and they form a large portion of the cliff face of the river escarpment. They can be examined on the face of Mt. St. Alban at the summit of the Kings road and at Cape Bon Ami, where a ladder down the face of the cliff at the end of the Portage road makes them accessible and they constitute the greater part of the bold front of Mt. St. Alban. Such fossils as they contain are quite distinctively of Helderberg age.

Beneath and conformable to the Bon Ami beds are the *St. Alban beds* with a fauna quite exclusively identical with the Helderberg (lowest Devonian) fauna of New York. These calcareous compact shales are to be seen in exposures along the shores of Cape-des-Rosiers cove at the foot of Mt. St. Alban. About 50 species have been identified from these rocks of which more than one half are found in the lower divisions of the Helderberg series in New York, while hardly more than one-fifth occur in the Grande Grève limestones. Access to these exposures requires the descent of the Kings road down the slope of Mt. St. Alban and thence across the fields to the shore of the St. Lawrence river.

Sir William Logan estimated the thickness of these limestones at 2,000 feet (610 m.) and of this the Grande Grève beds include approximately 600 feet (180 m.). The boundary, however, between the sub-divisions is not a sharp one, but in all, the beds afford a total not paralleled in the Devonian section at Percé. In fact the entire series is wanting elsewhere and in all the other Gaspe folds, so far as known, except so far as represented by the

*The fauna of all these Devonian beds has been described in detail by Clarke.

Percé Rock limestone which conforms faunally with the Grande Grève beds. The absence at Percé of the major part of the Devonian limestone series serves to indicate how extensively the formation has been lost by faulting out rather than by lack of continuity.

Unconformity between the Devonian limestones and the Cape-des-Rosiers slates.—Similarly the entire representation of the Silurian and Ordovician, as indicated in the Percé section (a minimum of 1,000 feet and probably much more), has been lost in the Forillon section, by the overthrust which has carried these Devonian limestones over the erect and distorted Rosiers slates of Cambrian (Cambro-Ordovician?) age. So far as we have any evidence, the vast overthrust of this Forillon fold is due to the resistance imposed by the crystalline horst lying at the north of the St. Lawrence river (Canadian shield) and the degree of the reaction is expressed both in the fold itself and in the great fault ('Logan's fault') which outlines the course of the river.

Relation af the limestones to Gaspe sandstone.—As observed, an actual unconformable contact of the limestones with the overlying sandstones is seen at Little Gaspe 1 ½ miles (2·4 km.) west of Grande Grève where the first ridge of sandstone mountains comes to the coast. Infaulted masses of these red sandstones in the limestones are also to be seen eastward of Grande Grève indicating the removal of an entire mantle of the Gaspe sandstone from above the limestones.

The Flora of the Gaspe Sandstone, by David White.—Gaspe is the most interesting locality for Devonian plants yet known in Canada. The Gaspe sandstones are remarkable for the abundant plant fragments, mainly representative of Psilophyton which occur in great numbers at some horizons, and which interestingly enough appear, at several levels, to be rooted in old soils. Fragments, frequently but slightly compressed, from this district are present in many of the museums of Europe, as well as in most of those in America. Gaspe was twice visited by Sir William Dawson, who described all the species reported from this region. The Psilophyton-bearing beds occur at many horizons in the section, one of the most interesting being near Watering brook on the north side of the bay. Several plant-bearing layers were described by Dawson as old soils. Associated with other plant remains are

numerous petrified trunks of the giant alga (*Prototaxites*) (*Nematophyton*). One trunk, partially exposed, was described as exceeding 3 feet (0·9 m.) in diameter.

At one place, near the middle of the section, a coal bed one inch to three inches in thickness, associated with highly bituminous shales abounding in remains of plants, and containing fragments of crustaceans and fishes, is said to occur in the midst of grey sandstones and dark shale which resemble ordinary coal measures. The coal, which is shining and laminated, has no underclay, and appears to consist of what was once a peaty mass of rhizomes of Psilophyton, which now lies between layers of laminated bituminous shale. This thin coal occurs near Tar point on the south side of Gaspe bay, a place named for the occurrence of a thick dyke of trap holding petroleum in its cavities. The coal is supposed to be of considerable horizontal extent, the Tar Point outcrop being provisionally correlated with a similar bed about 4 miles (6·4 km.) distant on Douglas river.

The plants described by Dawson from Gaspe include *Prototaxites logani*, *Prototaxites* (*Nematoxylon*) *crassum*, *P. tenue*, *Stigmaria areolata*, S. *minutissima* (the latter species being perhaps based on the rhizones of Psilophyton) *Didymophyllum reniforme*, *Calamites inornatus*, *Annularia laxa*, *Lepidodendron gaspianum*, *Leptophleum rhombicum*, *Lepidophloios antiquus*, *Psilophyton princeps*, *Psilophyton robustius*, *P. elegans*, *Arthrostigma gracile*, *Cyclostigma*, *Cordaites angustifolius* and *Parka* related to, though smaller than, the Scotch *P. decipiens*.

The plants in the Gaspe section represent the Psilophyton-Arthrostigma flora, which preceded the Archæopteris flora The genus Archæopteris is present practically everywhere in the floras of the Upper Devonian in Europe and America, whereas the typical *Psilophyton princeps*, including the spinous forms, together with *Psilophyton robustius*, *Psilophyton grandis* and *Arthrostigma*, are characteristic of a lower zone in both Canada and the eastern United States. This older flora which is found in the Chapman sandstone in Maine, seems hardly to have survived the Hamilton group, above which (especially above the Portage) the Archæopteris flora reigns to the close of Devonian time.

Extension westward of the Devonian limestone series.— In the direction of the mountain trend the limestones have been traced well inland along the course of the Dartmouth river and southward, but are here mostly exposed in the ridge summits by erosion of the sandstone mantle Their relation there to the rest of the Palæozoic series is not yet fully understood.

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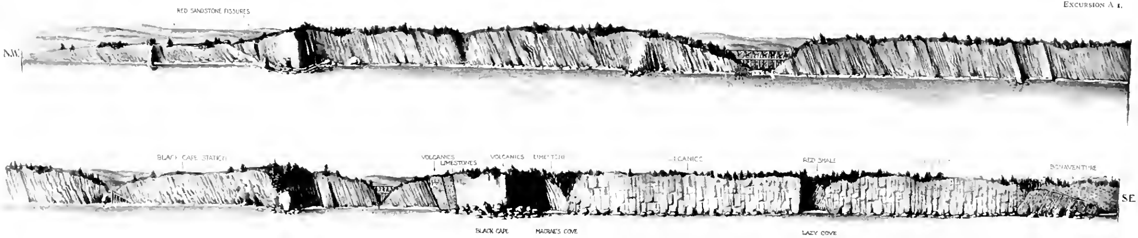
BLACK CAPE SILURIAN SECTION.

Black cape on the north shore of the Bay Chaleur, is immediately east of the Little Cascapedia river and 70 miles (112 km.) from Matapedia. The rock section here is of special interest for its extraordinary development of the Silurian, the shore section from the mouth of the



The Silurian section at Black Cape, Chaleur bay.
(The lower part is continuous with that at the top)

river named to Black cape itself displaying an unduplicated thickness of fully 7,000 feet, (2,130 m.) of strata.

In this Silurian section the strata are nearly all calcareous with intercalations of red shale near the top. They stand at high angles to the horizon, usually dipping 60-80° S.E., but these dips vary somewhat though without uncomformities. The eroded edges of the strata are overlain elsewhere in the region by the red sands and conglomerates of the Bonaventure formation, and there are several considerable fissures in the Silurian limestones of this section which are filled in with red sand derived from the overlying beds. All these occurrences indicate land exposure of the Silurians during all the early and middle Devonian time.

The base of the section at the west begins with greenish, highly nodular lime shales, very compact and heavy bedded, weathering out into irregular and gnarled shapes. These alternate with more highly calcareous shales and compact limestones of red and ochreous tints. These compact limestones contain Stricklandinias of great size (*S. gaspensis*, Billings) and in great number and with these are Spirifers of the *S. radiatus-niagarensis* type and occasional Whitfieldellas. Throughout the lower beds the rest of the fauna is largely of Stromatoporoids and corals which occur in enormous quantity and great diversity. There are Halysites of several species, having horizontal values, Favosites and Alveolites of great size, Heliolites, Syringopora, Eridophyllum in extensive colonies, Zaphrentis and other cyathophylloids in considerable variety. Additional species in these lower beds are Calymmene, Chonetes, *Atrypa reticularis* (Silurian type), Tentaculites, cyclostomatous gastropods, etc.

At an elevation in the series of about 1,500 feet (450 m.), where the scraggy limestones continue, there is some indication of change in the fauna by the addition of brachiopods of the genus Camarotoechia, Rafinesquina, the cephalopods Orthoceras, Trochoceras, etc. From Howatson's (elevation in section 1500 feet) eastward, the scraggy limestones continue as far as the breakwater. Then follows (at 6,500 feet or 1,980 m.) a heavy mass of sandy shale. This sedimentation continues sandy to near the end of the section which terminates at the volcanic mass forming Black cape, but toward the top the sands become interlaminated with thin beds of volcanic ash, with red and purplish shale and eventually calcareous and

variegated beds succeed to these, becoming in places compact limebanks entirely constituted of the debris of fossils.

These upper sandstones and sandy shales are remarkably profuse in corals, some of the species being palpably unlike those of the lower beds. The volcanic mass which forms Black cape itself and against which these upper strata abut presents a total sea face of 4,600 feet (1,400 m.) and within it are two notable inclusions or separate masses of Silurian strata. The first of these is in Macrae's cove, 600 feet (180 m.) from the beginning or base of the intrusive and the second at Lazy cove, $\frac{1}{3}$ mile (0·5 km.) further east. The intrusives are interbedded but the necessary study of the fossils is yet wanting to determine whether these fossiliferous masses are or are not additional parts of the section. At Macrae's cove the thickness of the sediments is 150 feet (45 m.) and in the narrower Lazy cove they are 75 feet (23 m.). These coves may be reached on foot along the beach by favouring tide. The volcanic cliff ends $\frac{1}{2}$ mile beyond Lazy cove and at its termination the red conglomerates of the Bonaventure formation lie against it at an angle of 30 degrees.

So far as at present indicated by the fossils, this section from base to top is of the age of the Niagara (exclusive of Clinton) or Rochester shale of the interior Silurian, though the assemblage will doubtless show a preponderance of Atlantic or European types which will bring it into more proper comparison with the Gulf sections at Arisaig and on Anticosti island. Its thickness is very great and in this respect the section overpasses any Silurian section known in America.

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[Note.—The Black Cape section has only recently come under close observation. It has now been studied in some detail and the fauna assembled, but identifications and classifications have yet to be made.]

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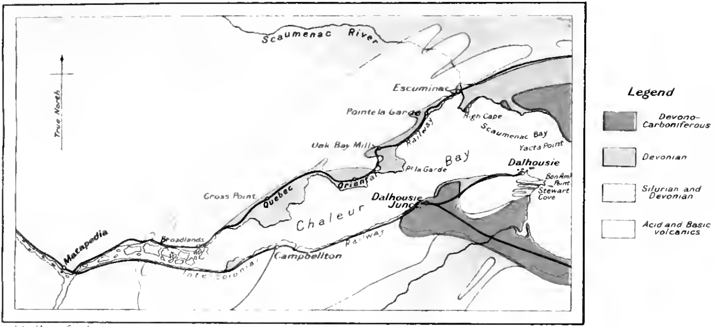

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Head of **Chaleur Bay**

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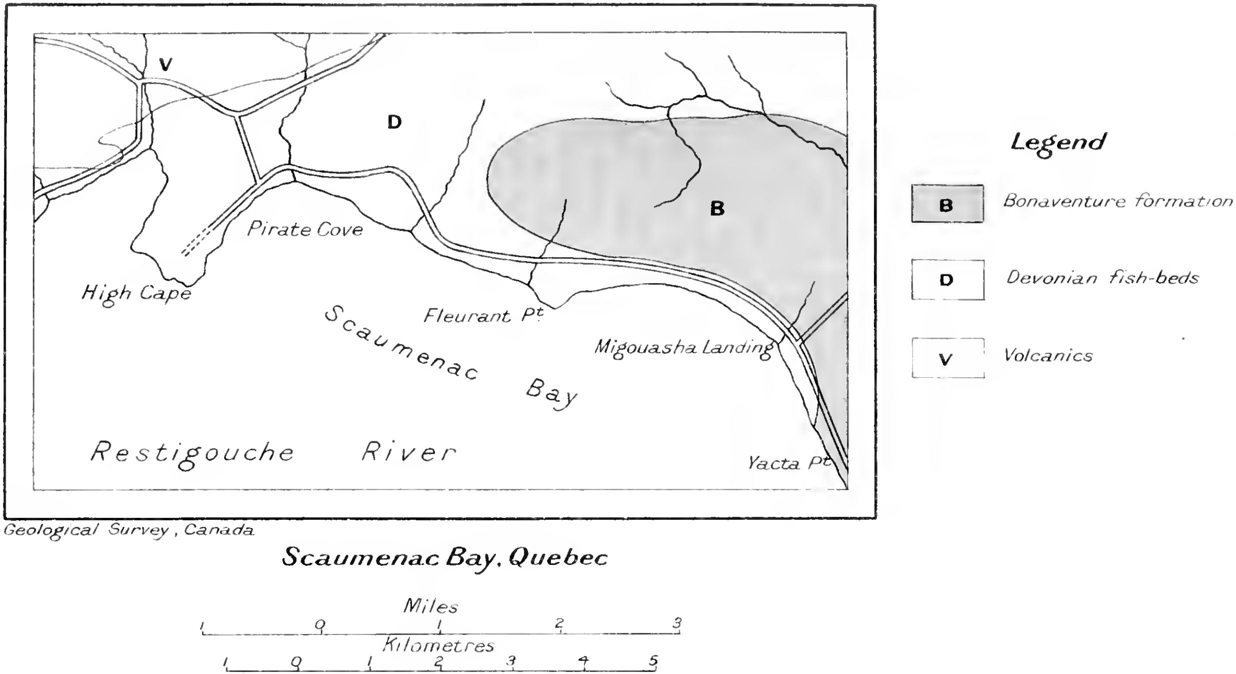

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Scaumenac Bay, Quebec

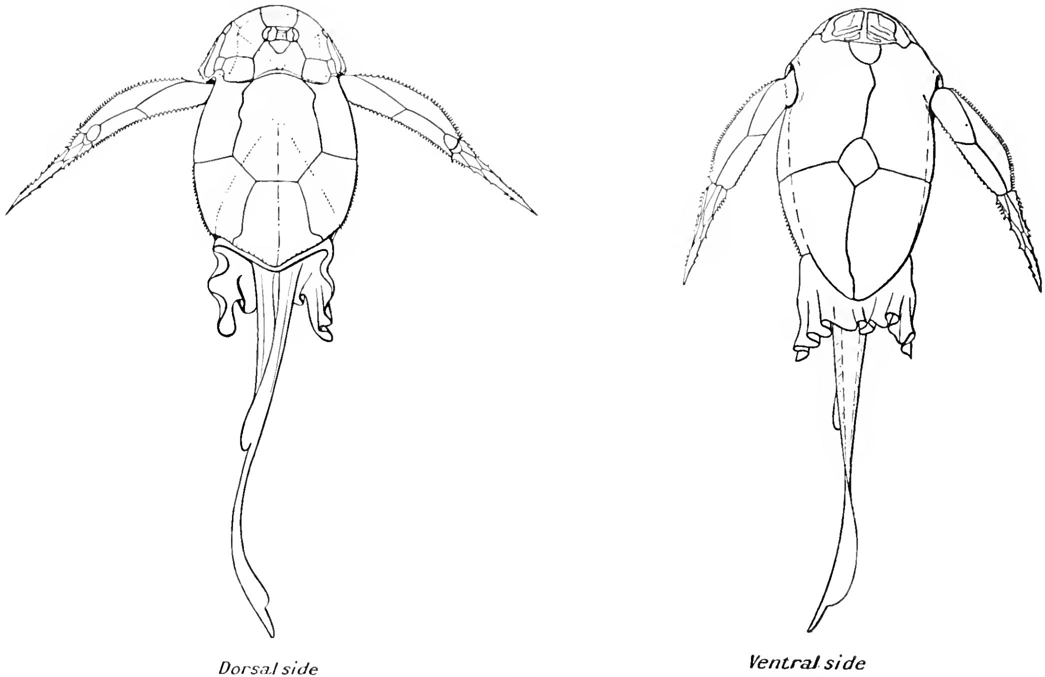
SCAUMENAC BAY.*

This is the locality of fish-bearing sandstones which are commonly regarded as of upper Devonian age. The beds face the water in layers having a low dip to the east, are bounded and overlain at the east by the red Bonaventure sands (Devono-Carboniferous) and at the west are limited, for this immediate region, by diabase intrusions. The inland extent of the rocks is not fully known but they have been recognized with their fossils 20 miles (36 km.) to the northeast on the Grand Cascapedia river, and there is evidence that there they lie above marine deposits with a lower Middle Devonian fauna. The fish beds are thus, in a broad sense, "Old Red-sandstone."

The ferry from Dalhousie stops at Maguasha Landing. Maguasha point lies 2 miles (3·6 km.) to the east. Scaumenac bay covers the coast line from Maguasha point to High cape at the west—3 miles (5·4 km.). Westward from the ferry landing along the shore, are exposures of very interesting and suggestive boulder beds, loosely cemented, interlaminated with sand layers, all lying beneath the fish-bearing strata. These boulders are largely limestone, freely containing fossils which are for the most part of normal marine Lower Devonian age. No fossils of later date than this age have been observed in them. There is no evidence of unconformity between them and the overlying beds.

The fish beds stand in high cliffs reaching 100 feet (30m.) or more in places and are essentially grey sand-shales and sandstones. The fish remains occur in the nodules and concretions, and in blocky parts of the shale beds. These beds afford the most abundant and some of the best preserved fish remains of the Devonian, although the genera and species are few. *Bothriolepis canadensis* is the most profuse in specimens and the extraordinary restorations by Patten are based on material obtained here. *Scaumenacia curta* is not uncommon in almost complete examples in the nodules. *Eusthenopteron foordi* often attains a size of 2-3 feet, and occurs in the shale layers. *Coccosteus canadensis* and *Acanthodes concinnus* are also among the commoner species. Other members of this fish fauna are *Cephalaspis laticeps*, *Euphanerops longaevus*,

*See Map,—Scaumenac Bay, Quebec.



Patten's restorations of *Bothriolepis canadensis* Whiteaves, from Scaumenac bay.

Diplacanthus striatus, *D. horridus*, *Holoptychius quebecensis* and *Cheirolepis canadensis*.

Intermingled with the fish remains are excellent examples of Devonian ferns which have been described by Sir Wm. Dawson.

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DALHOUSIE.*

South of the village of Dalhousie (1·5 m.) is Dalhousie mountain, an intrusive mass, partly rhyolitic, from which depart, toward the east, apophyses of diabase, varying in width. The water front of the village and the rocky islets skirting it belong to the northernmost and broadest of

*See Map—Dalhousie.

these volcanic arms (*Apophysis 1*). From the station eastward to Inch Arran point and light (1·5 miles) the shore cliffs are entirely of this rock, and on the Inch Arran cliff there are conspicuous inclusions of crystalline rocks surrounded by radial fracture and shrinkage lines. From Inch Arran (at low tide) along the shore past the Bon Ami islets and the "Gateway", the diabase of this apophysis continues to Stewart's or Fossil cove.

The Devonian section of Stewart's cove extends along a sea frontage of 1,700 feet (510 m.), but is divided by *Apophysis* 2, which has a 900 foot (280 m.) section. The fossiliferous strata are bounded on the south by *Apophysis* 3, and the actual exposed thickness of these sediments is about 430 feet (130 m.). The rocks are soft calcareous shales with thin limestone bands, thicker toward the top and hardened at contact with the diabase (*see* contact between shales and *Apophysis 2*). The strata have a uniform dip of 70°-75° N.E.

Apophysis 1 lies above these beds, but their contact is buried under the beach sand.

The highest beds are, beginning at the north:

1 Coral limestones with very abundant and diverse *Favosites;* also *Zaphrentis* and *Halysites*......	25 ft. (8 m..)
2. Barren shales................................	15 " (4·5 m.)
3. *Ash beds* with *Rensselaeria stewarti*	1 " (·3 m.)
4. Calcareous shale with gastropods (Coelidium)..	2 " (·6 m.)
5. *Ash beds* alternating with thin limestones and shales all highly fossiliferous. Ash beds with *R. stewarti*................................	30 " (9 m.)
6. Soft shales with lamellibranchs................	10 " (3 m.)
7. Thin limestones and soft shales profuse in corals and brachiopods..........................	95 " (29 m.)

Apophysis 2. In the middle of this is a detached mass of hardened glazed Devonian shale 30 by 15 feet (9 by 4·5 m.), at an angle to the normal dip; then follow from the south end of the volcanics downward:—

8. Compact limestone..........................	10 " (3 m.)
9. Coarse *ash bed*	12 " (3·6 m.)
10. Impure limestone with shale..................	165 " (50 m.)
11. Calcareous shale with *Sieberella pseudogaleata* and corals................................	30 " (9 m.)

A fauna of 80 species has been described and illustrated from these beds by Clarke and their vertical range through

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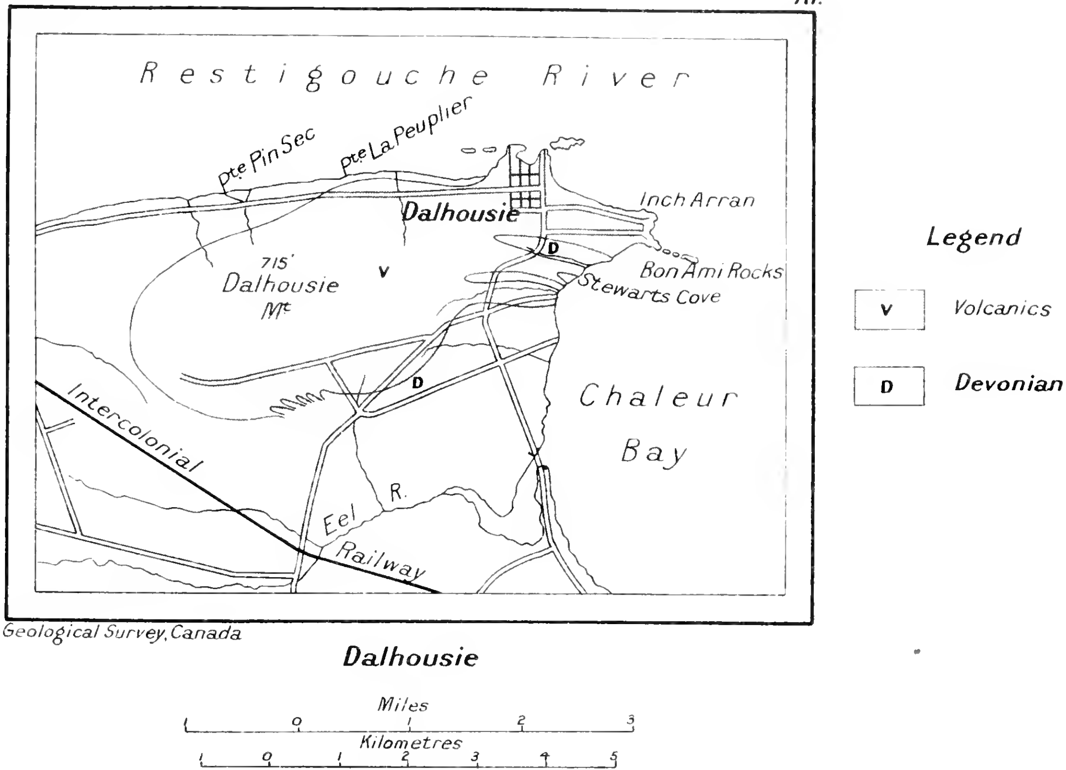

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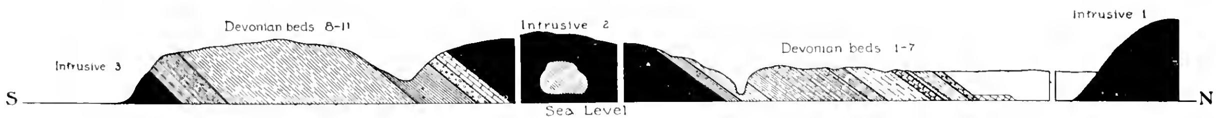

Section of the marine Devonian strata, Stewart's Cove, Dalhousie, N.B.

the section plotted. The fauna is rich in turrillated gastropods of the genera *Melissosoa* and *Coelidium*, lamellibranchs of the genera *Pterinea*, *Pteronitella*, *Mytilarca*, *Carydium*, *Palaeoneilo* and very profuse in the brachiopods *Leptaena*, *Stropheodonta*, *Strophonella*, *Spirifer*, *Leptaenisca*, *Orthis*, all of Helderberg species and types, and Rensselaeria of widespread early Devonian aspect. The beds are regarded as equivalent in fauna with the Helderberg of New York and the sea which deposited them, to have had direct connection with the interior Appalachian sea by one of several well defined Devonian sea ways parallel to the Appalachian axes. This channel or trough carried a very different assemblage of Helderberg species than the contemporary channel (St. Alban) in northern Gaspe (see p. 92).

Two miles southwest from this exposure, along the Eel River road and closer to the body of the volcanic mass is a second section of these sediments, 200 feet in length, in which are 5 interbedded deposits of volcanic tuff and ashes, in part carrying fossils.

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CHALEUR BAY.

PHYSIOGRAPHIC NOTE.

(J. W. Goldthwait.)

Chaleur bay, like the smaller Miramichi on the south and the greater St. Lawrence on the north, is a broad river valley which has been deeply drowned beneath the sea. At its head, west of Campbellton, it narrows to a slender point, into which the Restigouche and Matapedia rivers discharge. Similar sharp re-entrants or tributary estuaries lie at the mouth of its other large branches, the Nipisiguit at Bathurst and the Nouvelle and Cascapedia rivers on the north side. The drowning seems to have taken place during the Pleistocene period.

In this narrower upper portion of Chaleur bay evidences of submergence seem nowhere to extend above 50 feet (15·2 m.). Apparently the ice sheet lingered longer here than over the coast beyond Bathurst, covering the ground during the greater part of the stage of post-Glacial submergence. In no other way does it seem possible to explain the complete absence of elevated beaches like those at Bathurst (195 feet or 59·5 m.) and the presence in their place, in the zone below 200 feet, of kames whose sides appear to be too steep to have been covered by the sea for even a short time since the ice sheet released them from its grasp.

According to Chalmers, the striae and direction in which boulders and till have been transported indicate that the ice which mantled the country around Chaleur bay during the Glacial period moved radially into it from the north, west and south, forming a local, estuarine glacier. In the later stages the ice seems still to have pushed down from the high interior of Gaspe through such valleys as the Cascapedia and Nouvelle, after it had disappeared as a sheet from the coast. The kames of the north shore of the bay, which lie unmodified on ground within the 200-foot limit, seem to demand this.

On the way from Campbellton to Bathurst the railway skirts the shore of the bay, affording distant views of the rugged plateau of the Gaspe peninsula. A mile beyond Nash creek it reaches the eastern end of the great Restigouche kame, a fairly continuous ridge which extends

nearly 12 miles (19 km.) along the shore. The track crosses it east of New Mills station. Like other kames of the upper part of Chaleur bay, and of its tributaries the Nouvelle and Cascapedia, this appears to be a river deposit, formed within or against the ice during the withdrawal of the glacier from the coast. The Restigouche kame is 175 feet (53·3 m.) high at its west end and 50 feet (15·2 m.) high at the east end. As would be expected, it is overlapped by the fossiliferous marine clays which register post-Glacial submergence.

Along the north shore of Chaleur bay not a sign of wave-built beach or of wave-cut cliff appears above 75 feet (22·8 m.) although the opportunity for them is the best. Here and there faint beach ridges are to be seen below the 75-foot mark, and at New Richmond marine fossils have been collected from clays and sands which reach up to 40 feet (12·2 m.). At no place, however, have shells been reported from altitudes as high as those on the south side of the bay. All the way along the shore from Chaleur bay around to Cape Gaspe the sea is trimming back fresh cliffs into the land. While there is nothing extraordinary about this in itself, it becomes important when this shore is compared with that of the St. Lawrence just around the end of Gaspe where a shelf 20 feet (6·1 m.) above the sea extends for three or four hundred miles along the coast recording a recent elevation of 20 feet. Around on the south side of the Gaspe peninsula the recent movement if any, must have been a subsidence, slowly deepening the water on the shelf, and facilitating the attack of the sea against the cliffs.

ANNOTATED GUIDE.

DALHOUSIE JUNCTION TO NIPISGUIT JUNCTION.

(G. A. Young.)

Miles and Kilometres.	
0 m. 0 km.	**Dalhousie Junction**—Alt. 79 ft. (24 km.). From Dalhousie Junction to Bathurst, the Intercolonial railway closely follows the southern shore of the Bay of Chaleur. Throughout nearly the whole distance the bold front of the Gaspe highlands are visible rising

Miles and Kilometres.

steeply from the north side of Chaleur bay to heights of from 1,000 feet to 1,500 feet (300 m. to 450 m.) above the sea.

The southern coast of the Bay of Chaleur from Dalhousie eastward is low. Inland the country rises very evenly and attains elevations of between 600 feet and 900 feet (180 m. and 275 m.) in a distance of between 5 miles and 10 miles (8 km. and 16 km.). Farther inland, altitudes of 2,000 feet (600 m.) or more are reached and in certain districts the country is very rugged.

As far eastward as Bathurst, the country to the south of Chaleur bay is mainly underlain by Silurian strata, in places richly fossiliferous. Lower Devonian measures probably occur, while near Bathurst there is a wide area of Ordovician. Various varieties of igneous rocks of plutonic and volcanic types are present. The measures in general are closely folded, in places crenulated, along axes pursuing courses that strike towards the northeast. The strata are also much faulted. Along the sea front is a very narrow, discontinuous fringe of the Bonaventure formation of early Carboniferous or possibly late Devonian age. The Bonaventure measures are flat-lying, almost wholly undisturbed. Their presence in a nearly undisturbed condition, on both sides of the Bay of Chaleur, apparently indicates that this wide, shallow depression originated in Devonian time.

Leaving Dalhousie Junction the railway runs through a low, wide valley underlain by the horizontal red conglomerates and sandstones of the Bonaventure formation. On the north side rise the ridges of basic rocks forming Dalhousie mountain.

The railway presently approaches close to the coast. The narrow fringe of Bonaventure beds continue for about one mile past Charlo.

9·9 m. 16·3 km. **Charlo Station**—Alt. 53 ft. (16·1 m.). Beyond Charlo for a distance of about 12 miles (19 km.), the railway traverses a zone in which Silurian sedimentary strata alternate with areas

Miles and Kilometres.

of basic igneous rocks. The Bonaventure measures are absent from the shore but form Heron island which lies a few miles east of Charlo. Approaching Nash creek, the low, red cliffs of the eastern end of Heron island are visible.

22·0 m.
35·4 km. **Nash Creek Station**—A mile beyond Nash Creek, the Bonaventure strata outcrop on the shore and extend eastward along it for 15 miles (24 km.).

25·0 m.
41·1 km. **Jacquet River Station**—Alt. 55 ft. (16·8 m.). A long narrow band of red 'felsites' (rhyolites?) extends inland from Jacquet river. The igneous rocks have been supposed to be of Pre-Cambrian age. Possibly the felsites are of Silurian or Devonian age as in the case of similar bodies occurring elsewhere in the great Siluro-Devonian area of northwestern New Brunswick.

To the east of Belledune river, 9 miles (14·5 km.) east of Jacquet river, the railway traverses a zone of black slates of late Silurian (Guelph?) age. Along the coast are outcrops of fossiliferous red, grey and black limestones with shales of various colours, and sandstones and conglomerates. These measures range in age from Clinton to Niagara and, possibly, Guelph. They are underlain by red shales, sandstones and conglomerates with a thickness as great as 1,000 feet (300 m.) or more. The total thickness of the Silurian beds is large but the strata are so closely folded and so much faulted that no reliable estimate of total thickness may be made.

34·4 m.
55·4 km. **Belledune Station**—Alt. 84 ft. (25·6 m.). After passing Belledune station, the railway traverses a circumscribed area of igneous and altered sedimentary strata. Igneous rocks are exposed in a number of rock cuts and two long cuttings occur in them on both sides of Elmtree river, $6\frac{1}{2}$ miles (10·5 km.) beyond Belledune. The igneous rocks include granite and diabase. The different varieties of igneous rock and the sedimentary strata which are possibly in part

Miles and Kilometres.

of Silurian, in part of Ordovician age, are intricately associated. In places gneissic rocks have developed apparently as the result of lit par lit injection of granite material into sedimentary beds.

Beyond the crossing of Elmtree river, the railway pursues a southerly course and traverses a band of closely folded Silurian measures. The Silurian strata are succeeded on the south by Ordovician beds; the line of contact passing westward just south of Nigadu river, $4\frac{1}{2}$ miles (7·2 km.) from Elmtree river. In the northern part of the Ordovician area, the measures are light coloured slates, sandstones and fine conglomerates possibly of tuffaceous origin. They are closely folded along east-west axes and are cut by numerous dykes of diabase. At one locality north of the crossing of Tetagouche river, the railway crosses an area of igneous rocks possibly including both tuffs and lavas.

51 m.
82·1 km. **Tetagouche River**—At the crossing of Tetagouche river are deep cuts in stratified sands and clays containing many shells such as characterize the Leda clay and Saxicava sands of the St. Lawrence valley. These unconsolidated, stratified deposits have a thickness of at least 100 feet (30 m.) and probably are much thicker.

Along the Tetagouche river at the railway crossing, occur black slates carrying a graptolite fauna of lower Trenton, (Normanskill) age. These black slates with associated beds of fine sandstone form a wide zone of closely folded strata stretching inland in a westerly direction.

54 m.
86·9 km. **Bathurst Station**—Alt. 45 ft. (13·7 m.). At Bathurst the railway leaves the coast. The town of Bathurst is visible from the railway. It is situated at the foot of the nearly landlocked bay into which empties the Nipisiguit river, one of the larger rivers of New Brunswick.

Leaving Bathurst station, the railway follows along the west bank of Little river. At the crossing of a large tributary and again farther

Miles and Kilometres.

south at the crossing of Little river, are exposures of biotite granite belonging to a large body which cuts and highly alters the surrounding Ordovician strata. The granites occupy an area of about 80 square miles; the granite body is presumably of much greater area than this since its eastern portion is hidden by a mantle of younger, Carboniferous strata.

57·4 m. 92·4 km. **Nipisiguit Junction.**

ANNOTATED GUIDE.

NIPISIGUIT JUNCTION TO BATHURST MINES.

(G. A. YOUNG.)

57·4 m. 92·4 km. **Nipisiguit Junction**—From Nipisiguit Junction the Northern New Brunswick and Seaboard railway runs southward up the valley of Nipisiguit river to Bathurst Mines distant about 17 miles (27·3 km.). The railroad for most of the distance, passes through the forest out of sight of the river. Along the river exposures of granite continue for a distance of about 6 miles (9·6 km.). From the southern boundary of the granite batholith to near the Great Falls on the Nipisiguit river, the exposed strata are apparently of Ordovician age—bands of dark slates like those on the Tetagouche river alternating with others of green, probably tuffaceous, rocks. The strata are closely folded and much faulted.

At about the fourteenth mile the wide stream bed of the Nipisiguit river is visible from the railway. About a mile farther, the gorge of the river below the Great Falls, comes into view. The lower portion of the gorge has been cut through black slates dipping upstream at high angles. The upper portion of the gorge is in quartz porphyry overlying the dark slates. At about the sixteenth mile, the crest of the falls may be seen from the railway, and from this point to Bathurst Mines the railroad passes close to the river edge through many cuttings in sheared quartz porphyry.

BATHURST MINES.*

(G. A. YOUNG.)

The iron ore deposits of Bathurst Mines occur in three main bodies or groups of bodies, the longer axes of which, at the surface run about north and south. These deposits occur within a limited area on the northern bank of Nipisiguit river and in the vicinity of Austin brook, a southeasterly flowing tributary of the main river. One of the groups of iron ore bodies known as No. 2 deposit, outcrops on the northeast side of Austin brook valley and extends northward for at least 1,200 feet (360 m.). Another ore body, known as No. 1 deposit, outcrops on the southwest side of Austin brook valley about 900 feet (275 m.) west of No. 2 deposit and extends southerly for several thousand feet. The third group of ore bodies known as No. 3 deposit, lies nearly due north of No. 1 body at a distance of about 800 yards (730 m.).

In the immediate neighbourhood of the ore bodies, all the rocks are of igneous origin and belong to three main types, namely, quartz-free porphyry, quartz porphyry and diabase. The rocks in the district are largely covered by drift and therefore the relationships existing between the different rock varieties has not been established, but it is assumed that the quartz-free porphyry and the quartz porphyry are closely related in origin and age and that the diabase occurs in dyke or sill-like bodies cutting the porphyries.

The quartz-free porphyry outcrops in the eastern and southwestern portion of the area; the quartz porphyry forms the central portion of the area; and the diabase occurs in the western portion. No. 2 deposit lies within and just along the boundary between the area of quartz-free porphyry on the east and the central zone of quartz porphyry; No. 1 and No. 3 deposits occur along the western margin of the zone of quartz porphyry near the area occupied jointly by diabase and quartz-free porphyry.

The quartz-free porphyry is usually of a dark greyish colour, is fine grained, dense, and contains very small phenocrysts of plagioclase feldspar. In most cases the rock has at least an irregular schistose parting and in many

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*See Map, Bathurst Iron Mine.

places has been sheared to a glistening or dull, sericite or chlorite schist.

The quartz porphyry varies in colour from very dark grey to light greenish grey, the lighter colours being characteristic of the more schistose varieties which grade into sericite schists. The rock, where not too much sheared, is crowded with crystal fragments of glassy quartz, white orthoclase and acid plagioclase feldspar.

The diabase is finely granular, in some cases nearly black in colour; in others pale greenish and then has a pronounced schistosity.

The ore has generally a prominent slaty cleavage, is fine grained, and is composed largely of finely granular magnetite with a variable amount of hematite. Slight variations in grain are visible along regularly alternating bands. The banding varies in degree from microscopic to very broadly developed, being indicated where coarse by the occurrence of various impurities distributed along bands. The ore has a general black colour, tinged greyish from the presence of minute grains of quartz and feldspar which in some bands are finely and uniformly disseminated, while in other cases they occur in lines, narrow streaks and lenticular areas. Considerable pyrite is present and tends to occur in large and small, elongated, lenticular aggregates. Quartz is relatively abundant occurring in veins and stringers. A large number of analyses indicate that the iron content of the ore ranges from 39·6 per cent to 58·7 per cent; sulphur from 0·009 per cent to 0·27 per cent; and, phosphorus from 0·385 per cent to 1·222 per cent.

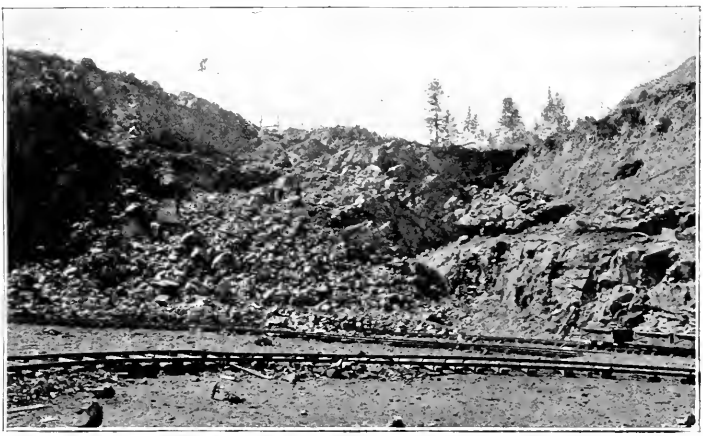
Examined in thin sections under the microscope, the ore is seen to be composed of minute, rapidly alternating bands of nearly pure iron ore, or of iron ore with considerable finely granular quartz and feldspar; and other bands of nearly pure quartz, with varying proportions of feldspar, iron ore, etc.

In the case of No. 2 body, a portion of its southern end, and of the east and west walls is visible. The greatest width of the body where stripped, is a little over 40 feet (12 m.). The containing walls are sharply defined, and the body appears to dip to the west at angles varying between 60° and 80°. The ore is banded and some quartz is present in comparatively large, irregular veins. Little or no pyrite is to be seen except immediately along the walls.

On the hanging wall-side, at a distance of about 150 feet (45 m.) from the ore, ordinary schistose quartz porphyry crowded with phenocrysts of quartz and feldspar is visible. At exposures intermediate between this and the ore body, the rock gradually assumes a more schistose habit. On the foot-wall side an analogous set of phenomena is visible but the rock there appears to be a quartz-free porphyry.

The southern termination of the ore body has been laid bare. The mass of ore ends in a number of angular, finger-like projections extending a few feet into the country rock and associated with considerable quartz.

In the case of No. 1 deposit, the foot-wall is exposed for a short distance. The rock, probably a much altered, schistose quartz porphyry, is very heavily charged with pyrite. It has a pronounced schistose parting along which



Bathurst Iron mine. No. 1 orebody. August, 1912.

occur seams and veins of quartz. The boundary of the ore body is remarkably sharp. The ore seems to end abruptly along the plane corresponding to that of the slaty parting and banding in the ore, and of the schistose parting in the wall rocks.

The ore bodies have the form of abruptly terminating beds or bands, with, in each case, a fairly constant thickness. The walls where seen, are always sharply defined and dip

westward at angles varying from 45° to nearly 90°. In the case of No. 1 deposit, the ore body at its outcrop at the northern end has a thickness of 105 feet (32 m.). In a drill hole which intersected the body at a vertical depth of 410 feet (125 m.), the ore body had a thickness of 65 feet (19·8 m.). As indicated by the results obtained from a magnetometric survey, the ore body has a length of about 2,000 feet (610 m.).

It is believed, for the following reasons, that the ore bodies have formed through the partial replacement of schistose quartz porphyry by iron ore, along sharply defined zones.

The prominent banding of the ore, sometimes on a coarse scale, sometimes microscopic in its fineness, is, when seen in thin sections under the microscope, very regular, and gives the impression of being an original structure, not a secondary one imparted in some way to the ore after its formation.

The parallelism of the banding of the ore (seemingly an original structure) and its attendant slaty cleavage, with the walls of the ore bodies and with the planes of schistosity in the neighbouring rocks, forcibly suggests that the ore has replaced a schistose rock, and has partly preserved the original schistose structure.

The finely granular quartz present throughout the ore, as well as the less abundant granular feldspar, may readily be regarded as representing original constituents of the replaced, schistose rock, possibly sheared quartz porphyry. That the original rock was schistose is supported by the fact that in all cases where observations were possible the country rock, as it neared the ore bodies, was found to be progressively more schistose.

Under the above hypothesis, the occasional narrow bands of dark green schist seen in No. 1 body may represent a rock variety that more strongly resisted the replacing action of the ore bearing solutions. The apparently basic composition of these bands, and the occurrence of schistose diabase along the western walls of the ore body, suggest that they may represent dykes of diabase.

As regards the quartz veins, in the case of a thin section of ore charged with small reticulated and crenulated quartz veins, it was seen that the alternating microscopically fine lines and extremely narrow bands of quartz, quartz impregnated with iron ore, and nearly pure iron ore,

conformed as nearly as possible to the intricate folding exhibited by the quartz veins. On the assumption that the ore and its structure are due to the replacement of schistose rock, the minutely corrugated forms exhibited by the ore represent a corrugated structure previously existing in the now replaced schist.

The appearance of the ore in thin section did not seem to indicate that the ore would fracture along the old corrugation planes, and so permit the formation of later quartz veins following similar crenulated courses, and, therefore, it is concluded that the veins did not originate after the formation of the ore.

The appearance in the thin sections of the bands or zones of quartz veins, and of the ore body as a whole, does not warrant any supposition that the quartz veins were bent after the formation of the ore.

It is true that the veins might have been formed contemporaneously with the ore, but, on the other hand, the puckering and bending of the veins in the ore are duplicated over a part of the exposures of country rock on the foot-wall of No. 1 body. This would indicate that the original rock had been twisted and bent, that quartz veins were introduced either before, during, or after the folding, and that after this the rock had been replaced by ore that still retains many indications of the original crenulations, as well as many or all of the quartz veins.

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ANNOTATED GUIDE.

NIPISIGUIT JUNCTION TO HALIFAX.

(G. A. Young.)

Miles and Kilometres.

0 m. 0 km. **Nipisiguit Junction.** — The Intercolonial railway about one half mile beyond Nipisiguit Junction, crosses Nipisiguit river and enters the great Carboniferous area of New Brunswick. Nearly the whole eastern half of the province, an area of about 10,000 square miles (26,000 sq. km.), is floored by Carboniferous measures. The strata are mainly grey sandstones, and red and grey sandstones and shales, of Millstone Grit (Pottsville) age. The measures over the greater part of the area are nearly horizontal and the land surface is very even, scarcely rising anywhere higher than 500 feet (150 m.) above the sea.

118·9 m. 191·3 km. **Moncton.**—Alt. 50 ft. (15 m.). Moncton is situated near the southern border of the New Brunswick Carboniferous area, the boundary being formed by a series of highlands extending along the coast of the Bay of Fundy. These highlands are underlain by deformed Pre-Cambrian and early Palæozoic strata associated with great volumes of igneous rocks. Along the southern margin of the Carboniferous area, older divisions of the Carboniferous are exposed in a folded and faulted condition.

Leaving Moncton the railway for some distance passes through a district of Carboniferous strata, in part disturbed, which extend eastward around the northeastern end of the upland of deformed Pre-Cambrian and Palæozoic rocks. After traversing this district, the railway crosses the low-lying Chignecto isthmus which connects New Brunswick with the peninsula of Nova Scotia. The isthmus is underlain by Millstone Grit strata and measures of late Carboniferous or Permian age. The strata lie in wide open folds.

Miles and Kilometres.

After crossing Chignecto isthmus the railway enters the low-lying portion of Nova Scotia which extends for many miles along the Gulf of St. Lawrence coast and reaches inland to the Cobequid hills. This low-lying region is floored with various divisions of the Carboniferous and also with strata of Permian age. The measures in places are closely folded and faulted while in other places they lie nearly horizontally or in simple open folds.

About 100 miles (160 km.) beyond Moncton, the railway crosses the Cobequid hills. This upland extends eastward from the head of the Bay of Fundy for 100 miles (160 km.). The highlands in places rise to heights of about 1,000 feet (300 m.) and are crossed by the railway through a pass having a summit elevation of 615 feet (188 m.). They are formed, in the main, of a complex assemblage of plutonic rocks, both acid and basic, and various schists. Along the southern margin of the area, strata of about mid-Carboniferous age are cut and altered by igneous rocks. Whether all the igneous rocks of the Cobequids are of post-mid Carboniferous age is unknown.

After crossing the Cobequids, the railway passes through a zone of disturbed Carboniferous beds flanking the Cobequids on the south, and then enters the low lying Triassic area which in part encircles the head of the Bay of Minas. This arm of the sea is an eastward projection from the Bay of Fundy.

310·2 m. 499·2 km. **Truro.**—Alt. 60 ft. (18·3 m.). Truro stands in the low-lying Triassic area at the head of the Bay of Minas. The Triassic measures are largely red sandstones and shales and are flat-lying.

Leaving Truro the railway for a few miles runs over the low Triassic area, after which it turns south and by means of a low divide, crosses the highland area which extends for 250 miles (400 km.) in a northeast-southwest direction and which forms the axis of the Nova

Miles and Kilometres.

Scotian peninsula. The highlands rise to a general elevation of between 700 and 1,000 feet (215 and 300 m.) above the sea, but in the low, very wide pass traversed by the railway, the summit elevation is only 141 feet (32 m.).

After leaving the low-lying Triassic area in the neighbourhood of Truro, the railway first traverses a district underlain by Carboniferous, perhaps in part Devonian, strata belonging to the horizon of the Union-Riversdale group and the Windsor series. Beyond this area, the railway enters the belt of Pre-Cambrian strata (the Goldbearing series), which with intrusive bodies of Devonian granite, stretch the whole length of the Atlantic seaboard of Nova Scotia. The Goldbearing series consists of about 35,000 feet (10,600 m.) of quartzites and slates; the quartzites are more abundant in the lower portion of the series while the slates predominate in the upper portion. The strata lie in large and small dome-shaped folds which occur along axial lines that in a general way strike northeast-southwest.

372 m.
597·1 km.

Halifax.—Halifax is the capital of the province of Nova Scotia. The city is situated on the western side of one of the numerous fiords that characterize the Atlantic coast of the province. The major portion of the city is underlain by dark slates of the upper division of the Goldbearing series. The strata are folded along axes striking about south-southwest. The northern end of the city and the country to the north are underlain by the lower quartzite division arranged in a series of folds parallel to those in the slate division. A short distance west of the city the sediments are bounded by a batholith of granite. Along the granite contact the slates have been highly metamorphosed, but they retain their normal dip and strike. Absence of any local disturbances of the strata due to the granite intrusions is characteristic of the whole area of the Goldbearing series.

ANNOTATED GUIDE

Halifax to Windsor.

(G. A. Young.)

Miles and Kilometres.

om.
okm.
Halifax. Leaving Halifax station, the Intercolonial railway passes rock cuttings in dark slates of the upper division of the Goldbearing series. The strata dip to the southeast at angles of from 20° to 65°. In a short distance the railway closely approaches the shore of the narrows connecting Halifax harbour with Bedford basin, and enters an area underlain by the lower quartzite division of the Goldbearing series. The strata dip regularly to the southwest at angles of between 50° and 80° and are exposed in rock cuttings along the railway.

4 om.
6·4 km.
Rockingham Station. One mile past Rockingham, at Birch cove, an anticlinal axis in the quartzites is crossed. On the north side of the axis, the strata, (exposed in numerous cuts), dip to the northwest at angles varying between 20° and 45°

Two miles farther, at Mill cove, a synclinal axis is crossed.

8.6 m.
13·8 km.
Bedford Station. Bedford is at the head of the inlet along whose shores the railway follows from Halifax. The depression of the inlet is continued inland by a valley bounded by hills rising to heights of 200 to 400 feet (60 to 120 m.). The railway crosses this valley and enters a low, rough, hilly country with many small, irregular lakes lying at various elevations up to 300 feet (90 m.) and more, above the sea.

Numerous rock cuttings in quartzites occur along the railway, the strata dipping to the southeast at angles of from 20° to 40°.

Two and one quarter miles (3.6 m.) beyond Bedford a low height of land with an elevation of 140 feet (42·6 m.) is crossed. The waters on the northern side of this divide drain northward to the Bay of Minas.

Miles and Kilometres.

One mile (1.6 km.) beyond where the railway crosses a small lake, the railway crosses an anticlinal axis. The Waverly gold district is situated on this anticlinal, one half mile to the east of the railway.

13·9 m. 22·4 km. **Windsor Junction.** Alt. 129 ft. (36·8 m.). The Canadian Pacific railway joins the Intercolonial railway at Windsor Junction. At a distance of about 1 mile (1.6 km.) from the junction, the Canadian Pacific railway enters a zone of dark slates belonging to the upper division of the Goldbearing series. The belt has a width of about $3\frac{1}{2}$ miles (5.6 km.) and in it the strata lie in two synclinal folds. On the northwest side of this belt of slates, the lower strata of the quartzite division again outcrop. The boundary between the two divisions crosses Fenerty lake—a long narrow lake along whose southeast shore the railway runs for some distance.

The band of quartzites has a width of $4\frac{3}{4}$ miles (7.6 km.). The strata lie in the form of an anticline whose axis strikes N.E—S.W. The measures in general dip at angles of from 50° to 65°. Leaving Fenerty lake whose waters are about 250 feet (76.1 m.) above the sea, the railway climbs to a height of 456 feet (139 m.) and recrosses the height of land separating the waters draining southeast to the Atlantic from those draining northwest to the Bay of Minas.

Three quarters of a mile (1.1 km.) beyond the crossing of the height of land, the railway enters South Uniacke gold district which is located on an anticlinal dome near the northwestern border of the quartzite belt.

23·7 m. 38·1 km. **South Uniacke Station.** Alt. 449 ft. (13·4.) South Uniacke station is close to the border of the quartzite belt. Beyond South Uniacke the railway crosses a belt of slates, $1\frac{1}{2}$ miles (2.4 km.) wide. The strata lie in two synclinal folds: the lower quartzite division is exposed in places along the intervening anticline.

Miles and Kilometres.

The railway passes along the western side of a small lake lying on the northwestern border of the slate belt. Beyond this point the railway enters a belt of the quartzite division and the strata are exposed in many rock cuttings.

26·8 m.
43·1 km.

Mount Uniacke Station. Alt. 509 ft. (155 km.). After passing a number of rock cuttings in the quartzite, or lower division of the Goldbearing series, the railway runs for some distance along the southern shore of a lake. This lake lies on the contact between the Goldbearing series and a large batholith of granite which extends for 100 miles (160 km.) to the southwest and occupies an area of,approximately, 3,000 square miles (7,800 sq. km.). This granite intrusion is of Devonian age. Rock cuts in the granite occur along the railway. A short distance farther, after passing the northern end of a lake, the railway traverses for about ½ mile (0.8 km.) a small area of quartzites entirely surrounded by granite. Beyond this for a distance of 1½ miles (2.5 km.) the railway passes through an area entirely underlain by granite. In the succeeding 1½ miles, (2.5 km.), the railway follows along the curving northern boundary between the granite and the bordering strata of the Goldbearing series. Finally passing away from the granite region, the railway recrosses the height of land (altitude of crossing, 412 ft. (125.1 m.) and begins to rapidly descend along a valley to the more even, lower country visible to the north. The rock cuttings at first are in quartzite while farther on they are in dark slates. The strata of the Goldbearing series occur in regular, parallel folds which are truncated by the granite batholith.

36·8 m.
59·2 km.

Ellerhouse Station—Alt. 258 ft. (78·6 m.). Beyond Ellerhouse the railway traverses a belt of the quartzite, or lower division of the Goldbearing series. The strata are exposed in a number of rock cuttings and along the walls of the gorge of the St. Croix river where this stream is crossed by the railway. Three

Miles and Kilometres.

quarters of a mile (1·2 km.) beyond the St. Croix river, the railway enters a narrow belt of Carboniferous strata consisting of shales, sandstones and conglomerates which are correlated with the Horton series. The measures dip towards the north at comparatively low angles. They extend in an east and west direction for about 6 miles (9·6 km.) and are interposed between the Pre-Cambrian Goldbearing series with its intrusive Devonian granites and the limestone, shale, gypsum, etc., of the Windsor series (Mississippian) flooring the low county to the north.

39·8 m. **Newport Station**—Alt. 119 ft. (36·3 m.).
64·0 km. Newport is situated on the southern boundary of the comparatively low area of Windsor series which extends northwards for about 13 miles (20·9 km.) to the Bay of Minas. Before reaching Newport and after passing it, gypsum cliffs and quarry workings are visible. To the west and southwest is visible the front of the highland underlain by the Devonian granite and the Pre-Cambrian Goldbearing series. This highland rises abruptly from the bordering lowland of Carboniferous measures, to heights of 600 feet to 800 feet (180 m. to 240 m.) above the sea.

45·5 m. **Windsor**—Alt. 26 ft. (7·9 m.). The town of
73·2 km Windsor is situated on the east bank of Avon river where it joins St. Croix river.

WINDSOR—HORTON.*

(W. A. Bell.)

INTRODUCTION.

The district herewith described borders on representatives of three main physiographic divisions of the eastern provinces of Canada. These are as follows: (1) the pre-Carboniferous uplands, (2) the Carboniferous lowlands, and (3) the Bay of Fundy or Triassic lowland.

*See Map— Windsor—Horton Bluff.

The present geographical location of these divisions is due primarily to Palæozoic constructive and mountain-making processes, as expressed in deposition, folding, and faulting, and secondarily to Mesozoic, Tertiary and Quaternary destructive and epeirogenetic processes, as expressed in erosion and vertical warping. The deformative processes of Palæozoic time have determined the general northeasterly-southwesterly trend of the structural axes, while the differential vertical movements of post-Palæozoic time, working largely independently of structure, have controlled the present surface features.

CRETACEOUS AND TERTIARY PENEPLAINS.

The pre-Carboniferous uplands comprise the highlands of New Brunswick, the Cobequid hills, and the Southern upland or plateau of Nova Scotia. Daly [**1**] has furnished evidence to support the hypothesis that these surfaces represent remnants of a once continuous and more extensive Mesozoic peneplain. The age of the peneplanation was assigned by him to the Cretaceous by correlation with the New England and southern Appalachian land forms. The basic argument for this interpretation is the remarkable discordance of surface form with underlying structure. Vertical uplift and warping, accompanied by southeasterly tilting, in early Tertiary time exposed the old-age surface to renewed differential denudation, resulting finally in the sculpture of a local Tertiary base—a levelled surface on the softer Carboniferous rocks. But the ancient complex of more resistant rock still upholds large areas of the older or Cretaceous plain and so preserves the historical record of erosion.

TRIASSIC LOWLAND.

The history of the Triassic lowland, or Bay of Fundy region, is necessarily involved in that of the Carboniferous lowland, but is further complicated by the addition of tidal scour to subærial processes as an active though variable denuding agent, and by the fact that the processes of destruction worked on a peculiar type of constructional topography, apparently the resultant forms of monoclinal faulting [**2**], parallel to the older land areas. The modified result has its expression in such features as the trap ridge of North mountain.

SOUTHERN PLATEAU.

The particular area to be described is an embayment of the Carboniferous lowland bordering the Southern plateau to the south and west, but merging into the Triassic basin of the Bay of Fundy to the north. It is drained by the Avon river and its tributaries. The prominent characters of the three physiographic divisions may be read within the district. The Southern plateau is seen rising abruptly on the south to a smoothly curving, timbered skyline at an average elevation of about 500 feet (152·4 m.). This plateau is marked by a gently rolling old-age surface interrupted only by occasional residual hills rising several hundred feet above the general level of the plain, and by the narrow, young gorges of the northerly flowing streams. The irregular veneer of glacial debris has so modified the pre-Glacial drainage that abundant lakes as well as large areas of marsh are now present on the divides. The underlying rocks are a thick series of slates and quartzites, known as the Gold-bearing series, and generally assigned to the Pre-Cambrian; they are closely folded, and intruded by granitic masses. A plateau extension also limits the district on the west, but, whereas the descent to the lowland in the south is abrupt, here on the west it is eased by rolling foothills. In the former case the slope is from hard resistant rock to soft marls and gypsum, whilst in the latter a stronger development of the more competent Horton series intervenes.

NORTH MOUNTAIN.

An outlying remnant of this plateau surface forms the crest of the trap ridge of North mountain, which extends in a very even line a distance of some 120 miles (193 km.) at an average elevation of about 550 feet (167·6 m.). This ridge is uniformly carved on a sheet of massive, compact trap, roughly 200 feet (61 m.) thick, of which the lowermost bed is an amygdaloid conformable with Triassic red sandstone. To the south it terminates in an abrupt escarpment. To the north the dip is gently towards the bay.

CARBONIFEROUS LOWLAND.

The Carboniferous lowland, which in this area encroaches upon the upland in narrow embayments, is a portion of the Tertiary base-levelled plain. The mildly undulating surface is underlain here almost entirely by Lower Carboniferous (Mississippian) rocks. These are divided into two formations, the Horton, and the Windsor, whose relations to each other and to the Carboniferous elsewhere have been a matter of considerable discussion. The Horton includes a series of black, plant-bearing shales interbedded with quartzose sandstones and seemingly overlain by coarse arkose grits, sharp quartz sandstones and brick red shales. The supposedly overlying Windsor formation comprises a series of brick red and greenish marls, thick beds of anhydrite or gypsum and of dolomitic fossiliferous limestones. Post-Lower Carboniferous (Mississippian) folding and faulting have greatly deformed this soft yielding series, and good field sections are lacking.

ANNAPOLIS-CORNWALLIS VALLEY.

The Triassic lowland lies adjacent to the Horton beds on the north, forming the fertile Annapolis-Cornwallis valley. The slightly rolling surface nowhere rises high above sea-level. Along the shore of the estuary softly rounded divides alternate with fertile stretches of level marsh. The South Mountain plateau or the Horton foothills rises abruptly on the south, whereas the North Mountain escarpment limits the valley on the north. The underlying rock is mainly brick red sandstone, distinctly cross-bedded, in places coarsely conglomeratic, dipping at low angles to the north or northwest away from the highland. Its ferruginous but highly calcareous cement renders it especially susceptible to the attacks of the weather, resulting in a sandy red loam peculiarly adapted to the culture of fruits.

ANNOTATED GUIDE.

WINDSOR TO AVONPORT.

Miles and Kilometres.

0 m. 0 km. **Windsor.**—Alt. 26 ft. (7·9 m.). From Windsor, the Canadian Pacific railway runs west of north, cutting across the mouth of

Miles and Kilometres.

the Avon embayment of the Windsor series (Mississippian—Lower Carboniferous), This embayment extends up the basin of Avon river in a southwesterly direction into the Southern upland for a distance of about 5 miles (8 km.). Along the southern border the rocks underlying the Southern upland are largely granite and the rise to the upland is abrupt, but on the west the area of the Windsor series is limited by the Horton formation, which forms a belt of foothills of variable width, between the Windsor lowlands and a spur of the Southern upland.

The Windsor rocks are exposed in broken sections on the Avon river above and below the railway bridge.

5 m.
8 km. **Mount Denson Station**—Alt. 40 ft. (12·2 m.). Less than ½ mile (0·8 km.) north of Mount Denson station the railway approaches close to the shore and from here an outcrop of Windsor anhydrite may be seen at a low point known as Aberdeen beach. This rock is very different from the gypsum at Windsor, as it is massive, evenly bedded, less disturbed, and of a snowy-white colour. It lies in a low syncline succeeded to the south by a flat anticline.

The margin of the narrow Windsor embayment is crossed at this point, and the railway from here onwards, passes over a northeasterly trending area of Horton rocks which extend out from a spur of the Southern upland. To avoid the hills farther west, the railway clings closely to the shore. It is this projection or spur of the Horton strata that is cut transversely by the Avon river, thus exposing the Horton section.

11·9 m.
19·1 km. **Avonport Station**—Alt. 57 ft. (17·3 m.). Avonport is within 1 mile (1·6 km.) of the northern termination of the Horton spur or where the Horton rocks sink beneath the Triassic lowland of Cornwallis valley. A short distance east of the railway station the exposures of the Horton series commence on the banks of the mouth of Avon river.

HORTON BLUFFS SECTION.

GENERAL DESCRIPTION.

The Horton series, which here flanks the Southern plateau, is exposed for nearly 3 miles (5 km.) along the tidal estuary of Avon river in the section known as the Horton Bluffs.

Looking northwesterly from the Avondale shore, Cape Blomidon, the westerly termination of the Triassic trap ridge of North mountain, may be seen standing prominently about 500 feet (152 m.) above the sea. The contact of the trap with the underlying sandstone is there about 200 feet (61 m.) above the valley floor. The low country intervening between this picturesque ridge and Avonport is a part of the Annapolis-Cornwallis Triassic basin. The contact of the Triassic with the Horton shales is concealed on the shore, but the low red bluff $\frac{1}{2}$ mile (0·8 km.) to the north is made up of heavily cross-bedded, wave-eaten, soft Triassic conglomerate of a dark grey or chocolate colour, consisting of well worn pebbles up to 4 inches or more in diameter of sandstone, red shale, quartzite and quartz, embedded in a matrix of subangular quartz grains, and bound by a ferruginous calcareous cement. The dips are gently northwestward.

The underlying Horton beds rest in a flat syncline, of which the northern limb is regular and moderately inclined, while the southern limb, though at first but slightly disturbed, becomes strongly folded and faulted against the succeeding arkose series. At the beginning of the section the black argillaceous or calcareous shales make up the low banks and pave the tidal flat in an overlapping series of broad plates. The average dip is here scarcely 7°. On numerous bedding planes abundant flakes of mica are conspicuous. Ripple marking is common; raindrop impressions may frequently be observed; and sun cracking is not at all rare. The most common fossils are the spore case of species of Lepidodendra, which are extremely abundant is some of the micaceous shales. *Lepidodendron corrugatum* Dn. and *Aneimites acadica*, Dn. the two most characteristic plants of the Horton, occur at various horizons, but they are nowhere abundant. A species of *Sphenopteris* is rather rare. In Dawson's collection occur in addition : *Lepidodendron aculeatum*, *L. sternbergi*, *L. dichotomum*, *L. elegans*,

L. tetragonum, *Strobila*, *Dadoxylon antiquum*, *Cordaites*, *Psilophyton plumula*, *Alethopteris lonchitica*, *Stigmaria*, and *Calamites undulatus*.

At the first prominent headland the beds are sharply flexed in the synclinal axis. Beyond, minor thrust slips render the dips more variable. A characteristic feature of these upper shale beds is the presence of large irregular septarian concretions. At the following headland there is a heavy channel deposit of sharp angular quartz sandstone, while about 150 yards (137 m.) beyond, there is an interesting horizon of Lepidodendra standing upright. Over thirty plants were counted within 10 yards (9 m.) of the section. They are all small in size, falling under 10 inches (25 cm.) in diameter, and the remains are now shale casts of the interior, all trace of the bark having disappeared. Just beyond the succeeding headland, perhaps 150 yards (137 m.) further, there are several bone beds, remarkable for the abundance of fish remains such as scales, spines, jaws, clavicles, and teeth. These are the remains of common elasmobranch and ganoid genera, such as *Strepsodus hardingi*, species of *Acanthodes*, and scales of *Elonichthys* and *Palæoniscus*.

The remainder of the section, where not concealed by drift, shows the strata in general maintaining their northerly dips but with frequent dislocation. Finally, however, the dips increase until the beds are standing almost vertically at the axis of a sharply closed anticline. Crumpling and faulting persist to the most important fault of the section, where the northerly dipping black shales abut against the southerly dipping grey arkose and brick-red shale. At other localities this arkose series is seemingly in conformity above the typical Horton, a fact which would indicate a downthrow here to the south. Similar arkose with interbedded shales carrying the Horton flora, occur in the brooks south of Windsor where it rests unconformably in steeply pitching contacts, on the pre-Carboniferous crystallines. A prominent feature of these beds, aside from their arkosic appearance and the chocolate colour of the shales, is the occurrence of channelling or local erosional unconformities between the sandstones and shales. From their highly disturbed condition near the fault, the beds soon resume a low northerly dip to the axis of a low anticline from which they dip gently southward beneath a heavy covering of drift. The next rock outcrop lies 3 miles

(4.8 km.) south exposing white, evenly-bedded anhydrite, probably belonging near the base of the Windsor, folded in a flat syncline with succeeding anticline, and striking S. 61° E. The average strike of the Horton beds is about S. 57° E.

The writer has made only a very rough estimate of the thickness of the Horton series. It is thought to be in the neighbourhood of 1,025 feet (312 m.) in the southern limb, while but 400 feet (122 m.) more or less is seen in the northern limb.

GEOLOGIC AGE OF THE HORTON SERIES.

The older geologists, Brown, [**7**] Jackson, Alger, and Gesner, [**8**] regarded the gypsum or Windsor series as equivalent in age to the New Red Sandstone, *i.e.* the Triassic. The Horton as a consequence, as well as from its plant remains, was thought to be a development of the Coal Measures. In 1842 Logan [**9**] visited the sections, and considered the Horton a phase of the gypsiferous series, assigning both to the Triassic. However, he submitted some of the Windsor fossils to de Verneuil and Count Keyserling who regarded them as identical with species from the Permian deposits of Russia, the Zechstein of Germany, or the Magnesian Limestone of England. Murchison [**10**] in his anniversary address to the Geological Society of London in 1843 also contributed to this view. However, Lyell's visit to the localities in 1843 initiated a new correlation. Fortified by both stratigraphical and palæontological evidence he announced the age of the gypsum formation as well as that of the Horton beds, to be Lower Carboniferous and therefore distinctly earlier than the overlying Productive Coal Measures. Of the Horton he writes: [**11** p. 209] "Both in the Windsor district and on the Shubenacadie, I found an intimate association between strata containing mountain limestone fossils, masses of gypsum, and coal grits, with Sigillaria and Lepidodendron, but no seams of pure coal in this part of the series." His general conclusions were abundantly verified by the work of Dawson [**3**, pp. 252–7]. The latter was, indeed, the first to give clear expression to the division of these beds into two distinct formations, naming what he considered the lower, the Horton series or Lower

Coal Measures, as differentiated from the overlying Windsor series. More recently, field geologists, especially Fletcher and Ells on structural and stratigraphic grounds, assigned much of Dawson's Carboniferous, including the Horton, to the Devonian. This reference gave rise to a discussion, not yet settled, which involves not only this series but the Riversdale and Union formations of Nova Scotia as well, and also the fern beds of St. John, New Brunswick. An interesting synopsis of the controversy was published by Fletcher in 1900 [**12**].

In later years the plants of these beds were submitted to Kidston of England and to David White of the U. S. Geological Survey, these two paleobotanists gave independent confirmation of the age of the Horton, Kidston [**13**] considering it was undoubtedly Lower Carboniferous, while White [**14**] stated that " the Horton plant terrane should, on purely paleobotanical grounds lie below the typical Carboniferous Limestone [Windsor series]; but I believe it should go hardly so low as the Ursa stage [uppermost Devonian], or below the boundary generally accepted for the Lower Carboniferous [Mississippian]". In comparison with the Mississippian beds of Pennsylvania and Virginia, Mr. White would place the Horton as nearly synchronous with the Pocono (Kinderhook). He also regarded it as the near equivalent of the Albert shales of New Brunswick and of the Calciferous Sandstone series of Scotland. A. Smith Woodward [**15**] has likewise pronounced on the Carboniferous age of the Horton fish remains, and finally L. M. Lambe, [**16**] who described the fauna of the Albert shales, has correlated these two series as quite, or nearly synchronous, and equivalent to the Calciferous Sandstone series as developed in Mid- and West Lothian and elsewhere in Scotland.

THE HORTON FLORA.

(David White.)

The Horton flora, like its probable contemporaries at the base of the Carboniferous in the Arctic regions of Alaska, Bear island, and Spitzbergen, and in Siberia, as well as in the Appalachian trough, is remarkable at once for its paucity in genera and species and for the great profusion of two or three very variable dominant plants. The fern-like plants, which probably are Cycadofilic, vary

specifically between the different regions of the Northern Hemisphere, but they everywhere show their common relation to a new and distinctly Carboniferous stock, so that in spite of varying generic names their consanguinity is unmistakable. Thus the *Aneimites* ("Cyclopteris" and "Adiantites"), *acadicus*, so characteristic of the Horton, is congeneric with and specifically close to the *A. bellidula* and other forms of the genus in the more northern regions, as well as probably with the genus Triphyllopteris of the Virginian region of the Appalachian trough. Some of the widely variant forms of the Horton plants are difficult to distinguish from the *Triphyllopteris virginiana* in the Pocono of the last-named region, though the species in their *ensemble* are distinct. Descendants of this stock are found in Eremopteris and possibly in Rhacopteris.

The stems described by Dawson as *Lepidodendron corrugatum*, the other monopolist of the Horton flora, present an almost bewildering cortical variation, which is well illustrated in the report of the "Plants of the Lower Carboniferous and Millstone Grit Formations of Canada." This singular and well marked Lepidodendroid type belongs to the older, composite, stock of the Devonian known as *Archæosigillaria*, in which the alignment of the leaf bases in vertical and transverse rows sometimes, when the growth was slow, produced vertical ribs resembling the Rhytidolepis group of Sigillariæ, while in other cases, especially when the growth was more rapid and the leaf scars were longitudinally more remote, it caused a verticillate aspect of the scars. The *Archæosigillaria* type of scar, first noted in *Archæosigillaria* ("*Lepidodendron*") *gaspiana* and *A. primæva*, the latter from the Portage group in New York, survive in *Eskdalia* and in *Bothrodendron*. *Archæosigillaria corrugata* is perhaps indistinguishable in any of its phases from the equally omnipresent and likewise monopolistic Lycopod described by Meek from the Pocono formation of the eastern United States as *Lepidodendron scobiniforme.* The latter is similarly varied in its cortical features. The Horton tree has its close correspondents in several contemporaneous Arctic species, such as *Lepidodendron glincanum.*

The dominant Cycadofilic and Lepidodendroid types of the basal Carboniferous flora of North America were evidently in a state of great plasticity and variation, under the new environmental conditions (coal formation) in

this continent at the beginning of the Carboniferous period.

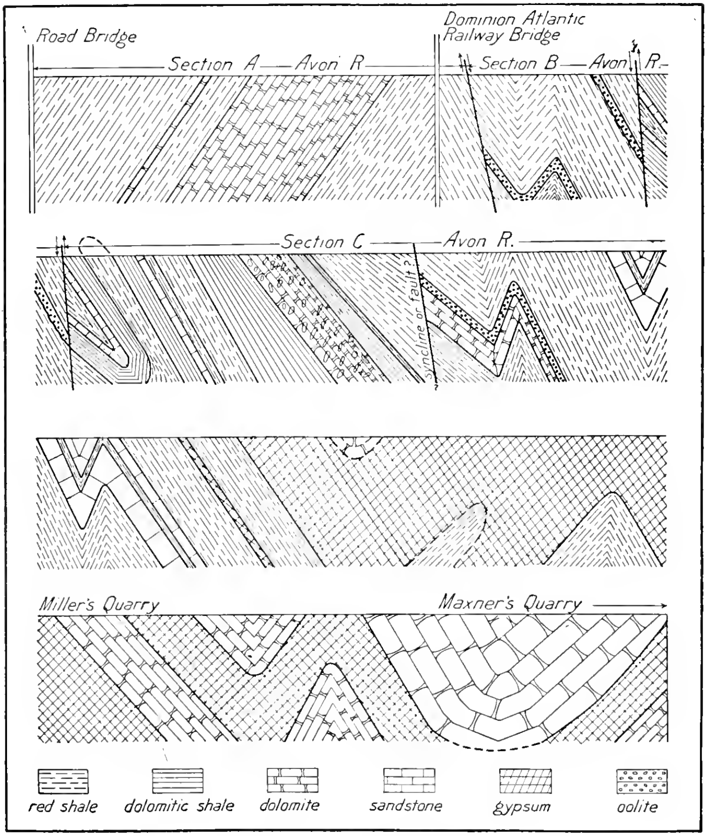
The Horton corresponds to the Pocono ("Vespertine"), which certainly is in part, at least, contemporaneous, in the central Appalachian trough, to the Cape Dyer beds, in the Cape Lisburne region of northwestern Alaska, to the coal-bearing basal Lower Carboniferous of Spitzbergen, Bear island, and Greenland, and probably to the lower portion of the Calciferous Sandstone series of Scotland.

THE WINDSOR SECTIONS.

GENERAL DESCRIPTION.

The sections about Windsor are so disturbed, disconnected and obscured with drift, that detailed field relations cannot as yet be given. The series comprises several hundred feet of soft brick-red and greenish-grey marls, interbedded with zones of gypsum and limestone, lying unconformably beneath deposits of Riversdale-Union age. Some of the limestone beds are of considerable thickness, while others occur as thin beds or zones between the shale or gypsum. The latter outcrops over a considerable portion of the area and has been extensively worked for many years. The type section of the Windsor limestones has been generally considered to be that exposed on the Avon river below the Windsor bridges. This section, however, has been given a prominence quite above its actual value in stratigraphy, as it is not only broken but also minutely deformed, so that the relations can only be appreciated by working in the mud at low tide. The accompanying section attempts to show the general relations of the rocks. The folding and faulting is locally very marked and the incompetent, yielding shales exhibit numerous pitching folds of small amplitude, frequently broken by small thrusts and with axial trends commonly parallel to the strike of the beds, while the thinner beds of sandstone or dolomite seem often to have yielded by brecciation in the closely mashed shales.

The Avon river marls and dolomitic limestones are separated by a thick zone of gypsum from the overlying Miller's Quarry dolomite beds. The latter at their full development are about 35 feet (7·6 m.) in thickness, lying between two zones of gypsum. Their contact with



Section from Windsor Bridges to Maxner's Point.

the overlying gypsum is obscured at the bridges but is well seen on the farther shore of the Avon, where 9 feet (2·7 m.) of transitional beds of gypsiferous shaly limestone carrying an extremely dwarfed fauna intervenes. The Miller's Quarry limestone is abundantly fossiliferous with Productids especially prominent. The gypsum above is again flexed in a shallow syncline at Maxner's point, preserving in its trough the Maxner's point dolomitic limestone. The upper beds of the limestone are likewise abundantly rich in fossils, especially in individuals of *Beecheria davidsoni*, *Dielasma sacculus*, *Pugnax sp.*, *Parallelidon dawsoni*, *P. hardingi*, and *Nautilus avonensis*. Following is a list of the more important species occurring in these Windsor sections:—

Vermes.

Cornulites? annulatus Beede. (*Serpulites annulatus* Dawson.)

Bryozoa.

Rhombopora exilis Beede, (*Stenopora exilis* Dawson.)
Fenestella lyelli Dawson.

Brachiopoda.

Beecheria davidsoni Beede, (*Athyris subtilita* Davidson.)
Dielasma sacculus Beede, (*Terebratula sacculus* Davidson.)
Martinia glabra Beede, (*Spirifera glabra* Davidson).
Spirifer cristatus Davidson.
Camarophoria? globulina? Davidson.
Rhynchonella pugnus? Davidson.
R. ida Hartt.
Productus semireticulatus Davidson.
P. dawsoni Beede, (*P. cora* Davidson).
Centronella anna Hartt.
Pugnax sp.

Pelecypoda.

Aviculopecten acadicus Hartt.
A. debertianus Dawson.
A. lyelli Dawson.
A. simplex Dawson.
Edmondia harttii Dawson

E. anomala Dawson.
Cardinia subquadrata Dawson.
Liopteria dawsoni Beede, (*Bakewellia antiqua* Dawson).
Modiola pooli Dawson.
Parallelidon dawsoni Beede.
P. hardingi Beede, (*Macrodon hardingi* Dawson).

Gastropoda.
Naticopsis howi Hartt.
N. dispassa Dawson.
Platyschisma? dubium Dawson.
Loxonema acutulum Dawson.
Murchisonia gypsea Dawson.

Pteropoda.
Conularia planicostata Dawson.

Cephalopoda.
Nautilus avonensis Dawson.
Gyroceras harttii Dawson.
Orthoceras dolatum Dawson.
O. vindobonense Dawson.
O. laqueatum Hartt.
O. perstrictum Hartt.

Trilobita.
Phillipsia howi Billings.

Ostracoda.
Beyrichia jonesii Dawson.
Leperditia sp.

GEOLOGICAL AGE OF THE WINDSOR SERIES.

Previous to Lyell's visit in 1843, the Windsor series was generally regarded as lying above the Coal Measures, probably from the resemblance of the former to the gypsum-bearing Permian rocks of Europe. Even Logan [**9**] in 1842 was of the opinion that "the gypsiferous strata and the associated shales, sandstones, and fossiliferous limestones are not only newer than the coal-measures, but overlie them unconformably," founding his conclusions respecting the geological age of the formation on

its organic contents. The fossils, he states, "have a decided generic agreement with the fossils of the Triassic period". Gesner [**8**] also, in 1843 included the Windsor in his New Red Sandstone division. Murchison [**10**], in the same year, suggested a Permian correlation on the basis of the fossil determinations of de Verneuil, Keyserling and himself, but Lyell [**7**] shortly afterward overthrew previous opinions by his evidence in favour of the Lower Carboniferous age of the series, including in his "Travels" a short list of the characteristic species of fossils.

It remained for Dawson [**3**, pp. 278-314] in 1868, to present the most comprehensive description and illustration of the Windsor fauna, finding many of the species closely allied with species of the Mountain Limestone of England, while de Koninck confirmed his views and correlated the formation with the Carboniferous Limestone of Visé in Belgium. Davidson [**18**] had previously described many of the brachiopods submitted to him by Billings. How and especially Hartt have also contributed to our knowledge of this fauna.

Little work has since been done in adding to the faunal relations stated by Dawson. Schuchert [**19**], after several visits to the Windsor locality, stated in 1910 that "the oldest fauna of this series at Windsor includes but few species, and these remind one of Kinderhook time. In the higher dolomites at Windsor a rich fauna appears that is very different from that in any American Mississippic horizon, and as it is also unlike those of Europe it is difficult to correlate. Seemingly it is of Keokuk time, yet it may be somewhat younger as Lithostrotion is reported at Pictou, which is not far from Windsor." This view finds further corroboration in Beede's [**20**] description of the same fauna found by John M. Clarke in the Magdalen islands.

Industrial Notes.

Gypsum has been the only mineral of industrial importance mined in the Windsor district. The great quantities and accessibility of this rock to navigable waters gave an early impetus to its exploitation, and quarrying operations have been carried on in the vicinity of Windsor for over a hundred years. In Haliburton's "History of Nova Scotia", 1829, it is stated that nearly 100,000 tons were annually shipped to the United States, where it was

utilized as a fertilizer. In 1910, 322,974 tons were quarried in the province, of which 10,500 tons only were used in the home manufacture of gypsum products, the balance being shipped to the United States.

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ANNOTATED GUIDE.

Windsor to Truro.

(G. A. Young.)

Miles and Kilometres.

0 m. 0 km. **Windsor.** Alt. 26 ft. (7.9 m.). The Canadian Pacific railway from Windsor to Truro runs in an easterly direction through a district whose western portion is underlain by Carboniferous strata belonging to the Windsor series. The gypsum beds and associated limestones and shales of the Windsor series, outcrop over a large area bordering the St. Croix river on both sides. They extend to the south for a distance of about 2½ miles (4 km.), and to the north for a distance of about 15 miles (24.1 km.) almost to the shores of the Bay of Minas. Over this wide area, the strata are folded, crumpled and doubtless, traversed by many faults. Though in many places the strata are vertical or steeply inclined, yet as a general rule, the angle of dip is not above 30°.

On the south, the Windsor series is bounded by the wide area of the Pre-Cambrian Gold-bearing series and the associated Devonian granites, traversed by the railway line from Halifax to Windsor. In places, narrow belts of Horton (lowermost Carboniferous) strata separate the Windsor beds from the older measures. The Windsor beds are unconformable to the Pre-Cambrian and possibly are also unconformable to the Horton. On the north, the Windsor beds are bounded by a narrow band, of irregular width, of sandstones, shales, slates, etc., which by Hugh Fletcher were considered to be Devonian and to unconformably underlie the Windsor strata. At least a portion of these so-called Devonian beds are the equivalents of the Horton series and therefore of Carboniferous age. Other portions may be the equivalents of the Riversdale-Union series and, if this be the case, are younger in age than the Windsor series.

Miles and Kilometres.

At a distance of 1 1-2 miles (2·4 km.) east of Windsor, the railway approaches the south bank of the St. Croix which flows westward to join the Avon at Windsor. From this point the railway for some distance closely follows the river and passes through several rock-cuts in gypsum. A short distance farther, the railway crosses to the north side of the St. Croix and follows up the valley of Hebert river, a small tributary of the St. Croix. The railway passes through a rock cutting in gypsum, and gypsum and limestone are exposed on the south bank of Hebert river.

6·3 m. **Brooklyn Station.**—Alt. 33 ft. (10 m.).
14·5 km. The railway follows Hebert river for 1 1-2 miles past Brooklyn and there turns to the north, crosses a low ridge (altitude 160 ft. or 49·8 m.) and descends to the valley of Kennetcook river. The country is gently rolling with relatively wide valleys.

12·1 m. **Mosherville Station.**—Alt. 39 ft. (11·9 m.).
19·5 km. The railway from Mosherville eastwards, ascends the wide, shallow valley of Kennetcook river which flows westward to join the Avon. The country is quite level and for a number of miles to the northward is boggy. As the river valley is followed eastward, it gradually narrows.

18·7 m. **Clarksville Station.**—Alt. 70 ft. (21 m.).
30·1 km. About 2 miles (3·2 km.) beyond Clarksville the railway crosses the Kennetcook (altitude 62 ft. or 18·9 m.). At this point the southern boundary of the area underlain by the Windsor series is about 2 miles (3·2 km.) south of the railway. To the south of the boundary lie so-called Devonian strata bordering a ridge of the Goldbearing series which terminates a few miles to the east. The "Devonian" strata encircle this ridge in anticlinal fashion and on the southern side of the ridge of the Pre-Cambrian Goldbearing series, are bordered by a wide area of the Windsor series. The 'Devonian" measures consist in part of sandstones and shales carrying, in places, thin coal seams. The "Devonian" strata appear

Miles and Kilometres.

to underlie the Windsor beds and for this reason were assigned to the Devonian by Hugh Fletcher. If, as the evidence seems to indicate, the "Devonian" beds so underlie the Windsor strata, it is still probable that they are of Carboniferous age and they may, in part at least be the equivalents of the Horton series.

16·5 m. 26·5 km. **Kennetcook Station.**—Alt. 97 ft. (29·6 m.). At Kennetcook station the area of the Windsor series traversed by the railway narrows to a width of less than 1 mile (1·6 km.). The narrow band of the Windsor series is bounded on both sides by "Devonian" strata. On the northern side, the "Devonian" measures occupy a ridge about 11 miles (17·1 km.) long and 2 miles (3·2 km.) wide. The strata forming this ridge seem to lie in a shallow synclinal. They carry thin seams of coal and as pointed out by Fletcher, they resemble the Millstone Grit, though he mapped them as Devonian. Practically nothing is known concerning the palæontological evidence of the age of the so-called Devonian strata. As already stated, it is entirely likely that portions of the "Devonian" strata underlie the Windsor series, but it is equally probable that other portions are younger than the Windsor series and that they may be of Millstone Grit age, perhaps are in part equivalent to the Riversdale-Union group. The non-recognition of the presence of Pennsylvanian strata in the "Devonian" areas may have been due to the lack of any pronounced unconformity between the Millstone Grit and older Carboniferous, a condition that obtains in a number of the Carboniferous districts of Nova Scotia.

20 m. 32·2 km. **Patterson Station.**—At Patterson and for several miles to the eastward, the railway passes through the "Devonian" area bounding, on the north, the narrow strip of Windsor strata.

Two miles (3·2 km.) to the east of Patterson station the railway again enters the band-like area of the Windsor series. About a mile farther the railway crosses the divide (altitude

Miles and Kilometres.

171 ft., 52·1 m.) between the headwaters of the westward flowing Kennetcook and of the easterly flowing Fivemile river. From this point, the railway descends the valley of Fivemile river to the Shubenacadie river.

35 m.
56·3 km. **Burton Station**—Alt. 141 ft. (42·9 m.). In the neighbourhood of Burton, the narrow area of Windsor strata that stretches along the upper part of the Kennetcook valley, joins a wider area which extends westward to the Avon at Windsor. This area extends eastward down Fivemile river valley but gradually narrows and near the mouth of Fivemile river leaves the river valley and dwindles away to a narrow strip only a few yards wide.

The valley of Fivemile river is very narrow. Exposures of gypsum, red shales and shaly limestone, and of red sandstone are visible at intervals.

One half mile above South Maitland, the river valley suddenly widens and the railway enters the area of "Devonian" strata that forms the south border of the Windsor area.

40·1 m.
64·5 km. **South Maitland Station**—Alt. 32 ft. (9·8 m.). A short distance beyond South Maitland the railway crosses Shubenacadie river. The dark strata of the "Devonian" are visible on the west bank of the river. The country on the eastern side of the river is underlain by strata of the Windsor series stretching for many miles in an easterly direction. After crossing the Shubenacadie, the railway for a short distance ascends the valley of a small brook, then bends to the north and climbs to the summit of a gently rolling country, (altitude of railway at summit, 235 ft. or 71·6 m.).

45·5 m.
73·2 km. **Princeport Station**—Alt. 212 ft. (64·6 m.). Beyond Princeport the railway crosses the northern boundary of the district occupied by the Windsor series and enters an area underlain by "Devonian" strata belonging to the Union formation.

Miles and Kilometres.

As the railway descends to the Triassic area bordering the Bay of Minas, this bay becomes visible and the gradually rising land on the opposite shore is seen.

50·8 m. 80·6 km. **Clifton Station**—Alt. 31 ft. (9·4 m.). Clifton station is close to the edge of the tidal flats bordering the estuary of Salmon river at the head of the Bay of Minas. Both sides of the river are bordered by Triassic strata. The Triassic strata are almost entirely red shales, sandstones and conglomerates and in this general district are nearly horizontal and quite undisturbed. The Triassic measures occur at intervals along the south shores of Minas Basin to the mouth of the Avon river and doubtless form the eastern prolongation of the Triassic area extending for above 100 miles (160 km.) eastward of the mouth of the Avon in the Cornwallis-Annapolis valley. The Triassic measures are not known to be fossiliferous but their correlation with the Newark series of the Atlantic states is well established.

57·8 m. 93 km. **Truro**—Alt. 60 ft. (18 m.). Truro is situated close to the southern border of the Triassic area, strata of the Union formation outcropping about ½ mile (0·8 km.) to the south of the railway station.

ANNOTATED GUIDE.

HALIFAX TO ENFIELD.

(G. A. Young.)

0 m. 0 km. **Halifax**—For description of route from Halifax to Windsor Junction, reference should be made to the itinerary of the journey from Halifax to Avonport, p. 133-4.

13·9 m. 22·4 km. **Windsor Junction**—Alt. 129 ft. (39·3 m.). Leaving Windsor Junction, the Intercolonial railway passes close to the western shore of a small lake. At the head of this lake, the railway enters an area underlain by dark slates of the upper division of the Goldbearing series. The

Miles and Kilometres.

slates form a belt about 3 miles (4·9 km.) wide in which the strata strike S.W.-N.E. and are folded along two synclinal axes.

Shortly after entering the slate belt, the railway approaches the head of Long lake and from this point follows northward along the western shore of the lake. The eastern shore of the lake, towards the foot of the lake, forms the western boundary of a granite stock having a diameter of about $1\frac{3}{4}$ miles (2·8 km.). The granite intrusion does not seem to have affected the structure of the surrounding beds of sedimentary rocks.

After passing the foot of Long lake, the railway turns easterly and runs parallel with the strike of the strata. The railway passes within sight of the head of Shubenacadie lake and crosses a small stream flowing into the lake. This small stream discharges the waters of a series of four long narrow lakes extending in a southeasterly direction up a narrow valley bounded by low hills rising to heights of between 150 feet (45 m.) and 350 feet (100 m.) above the sea. The most southerly of these four lakes is only 92 feet (28 m.) above the sea and distant only 3 miles (4·8 km.) from the Atlantic, being separated by a divide with an altitude of about 95 feet (28·9 m.) from a lake draining into Halifax harbour.

21·3 m. **Wellington Station**—Alt. 76 ft. (23·2 m.).
34·3 km. Beyond Wellington station the railway passes through several rock cuttings in dark slates, and as it approaches the eastern shore of Shubenacadie lake, enters a wide band of strata of the lower, quartzite division of the Goldbearing division. The strata in this belt are folded into two main anticlinal and a number of subordinate folds.

23·1 m. **Grand Lake Station**—Alt. 58 ft. (17·7 m.).
37·2 km. From this station is visible the high ridge (altitude 600 to 750 feet or 180 to 215 m.) bounding the Shubenacadie valley on the west. For some distance past Grand Lake station, the railway follows the shore of Shubenacadie

Miles and Kilometres.

lake and passes through rock cuttings in the quartzite series. Beyond this the railway passes along the western shores of a small lake and at Sandy Cove again approaches the shore of Shubenacadie lake.

25 m. **Sandy Cove Station**—Alt. 62 ft. (18·9 m.).
40·2 km. A short distance beyond Sandy Cove, the railway swings away from Shubenacadie lake and enters the Carboniferous area of the valley of Shubenacadie river which flows from the lake of the same name. The Carboniferous strata consist of beds of gypsum, limestone, shale, etc., and presumably belong to the Windsor series (Mississippian). The boundary between the Carboniferous strata and the Goldbearing series runs in a general easterly direction and for some distance is rather closely followed by Shubenacadie river. The railway crosses this stream a short distance from Enfield.

27·7 m. **Enfield station**—Alt. 63 ft. (19·2 m.).
44·5 km.

THE GOLDBEARING SERIES OF NOVA SCOTIA.

(E. R. Faribault.)

INTRODUCTION.

The Goldbearing series of Nova Scotia occupies the whole southern part of the peninsula of the province, extending along the Atlantic coast from Canso to Yarmouth. The series consists of a great thickness of conformable quartzites and slates closely folded in long east and west anticlines and intruded by many large batholiths of granite and some dykes of diabase. In the neighbourhood of the granite the sediments are metamorphosed into gneiss and schists. The age of the series cannot be determined by palaeontology as it is practically barren of fossils. From lithological analogy the strata have been regarded until recently as Lower Cambrian, but they are now believed to be late Pre-Cambrian in age. The gold deposits are in the form of quartz veins, chiefly interbedded, which are found aggregated in large numbers on the domes of

Anticline in the Halifax slate formation, showing the bedding and cleavage planes, interbedded and cross veins, and the arch-core of the fold plunging 5°, at eastern end of dome. The Ovens gold district, N.S., 1909.

pitching anticlines. Gold was discovered about fifty years ago and since that time the district has received the attention of many geologists.

The series is remarkable perhaps not so much for the amount of precious metal produced as for the enormous thickness of conformable sediments exposed, for the interesting variety of schists produced by igneous and dynamic agencies, and more specially for the beautiful dome-structure of the interbedded veins, the origin of which has provoked the constructive imagination of geologists for the last fifty years.

The geological structure of the greater part of the area of the series, from the eastern extremity to Liverpool and Kentville, has been surveyed in considerable detail for many years by E. R. Faribault [**10**], and the results have been published by the Geological Survey on map-sheets on the scale of one mile to an inch, on detailed plans of mining districts, and in many partial reports contained in the annual Summary reports. The southwestern portion of the region was mapped and reported on with less detail for the Geological Survey by L. W. Bailey. In the report compiled by W. Malcolm [**11**] and published in 1913 by the Geological Survey, entitled "Gold Fields of Nova Scotia", is presented a comprehensive and complete record of the results of the investigations made in the field. The present review of the subject is largely an abstract of that report.

The whole surface of the area of the Goldbearing series has been subjected to extensive erosion and all that remains of what was probably once a highly elevated mountain system, is a plateau reduced nearly to sea-level, showing the upturned edges of the closely folded beds and the low granitic masses that intruded them. The plateau has a general southerly slope towards the Atlantic, and its northern limit forms a long escarpment whose elevation varies in altitude from 500 to 800 feet (152 to 243 m.).

THE GOLDBEARING SERIES.

The Goldbearing series is one of the oldest series of sedimentary rocks in the province. It extends along the Atlantic coast the whole length of the peninsula, but is not represented in Cape Breton Island. The extreme length of the series from Canso to Yarmouth is 275 miles (442 km.) and the width varies from 10 miles (16 km.) at the eastern

end, to 75 miles (120 km.) at the western. Its area is estimated to be 10,250 square miles (26,568 sq. km.) or about half that of the entire province. Of this area, 4,000 square miles (10,368 sq. km.), or about one third, is occupied by intrusive granite.

This series was given the name of Meguma series in 1904 by J. E. Woodman [**6**]. It has however, been known so long and described so often under the name of Goldbearing series that it is thought better to retain that name.

The sedimentary rocks consist essentially of a great series of quartzites and slates apparently conformable throughout, with practically no limestone nor conglomerate. The series has been divided lithologically into two distinct, conformable formations, the lower known as the quartzite or Goldenville formation, and the upper known as the slate or Halifax formation. In King's county, south of the Cornwallis Valley, the slates of the Halifax formation are overlain, apparently conformably, by a few thick beds of pinkish-white, massive quartzite and a series of dark and fawn-coloured slates which are nowhere else represented along the Atlantic, and to which is now given the name of Gaspereau formation. But, until the conformity of these two formations has been proved conclusively, the Gaspereau formation can only be considered as a probable part of the Goldbearing series.

The total known thickness of the Goldbearing series, exclusive of the Gaspereau formation, is estimated to be 35,460 feet (10,808 m.), or nearly seven miles and including the probably conformable Gaspereau formation, 38,260 feet (11,662 m.) or nearly $7\frac{1}{2}$ miles.

Goldenville Formation.

The Goldenville formation consists mostly of thick-bedded compact, greenish and bluish grey quartzose sandstone, or quartzite, generally feldspathic and micaceous, often holding large cubes of iron pyrite and weathering light rusty grey. Interstratified with the quartzites are numerous beds of argillaceous, siliceous and micaceous slates of various shades of grey, sometimes arenaceous and passing into quartzites, and occasionally calcareous or pyritous. Towards the base, the slate beds become more numerous and often attain a considerable thickness. In the western end of the field at certain horizons, the slate

beds diminish in thickness and number and become very rare, while the quartzites increase in thickness and become massive, coarse and more siliceous. The thickness of the Goldenville formation, estimated to be 16,000 feet (4,877 m.) at Moose River, Halifax county, was found by Faribault in 1912, to exceed 23,700 feet (7,242 m.) on Liverpool bay, Queens county.

Halifax Formation.

The Halifax formation is composed essentially of argillaceous and siliceous slates of different colours, but mostly dark grey and black, graphitic and pyritous, passing at certain horizons into greenish and bluish grey talcose argillites, or into ribboned grey and light grey, chloritic, arenaceous beds. The black slates have numerous layers of flinty flags heavily charged with small cubes of pyrite which also occurs in massive form between the beds. The base of the formation is characterized, in some places to the eastward of Halifax, by a few beds of siliceous limestone. At the eastern end of the field the line of demarkation between the Goldenville and this formation is well defined by a sudden change from quartzite to slate, but at the western end the transition is more gradual and beds of quartzite are found interstratified with the beds of grey arenaceous slates of the overlying formation.

The thickness of the Halifax formation, as measured on the Black river to the base of the Whiterock quartzites of the Gasperau formation, is 11,700 feet (3,566 m.).

Metamorphic Phases.

Crystalline schists and gneisses of various kinds are found rather widely distributed throughout the field, but are of limited area. They usually occur in more or less continuous zones surrounding the granite masses, but they are also found in zones or irregular patches several miles distant from any outcrops of granite.

The gneisses consist chiefly of quartz and mica and are foliated and coarsely crystalline. The schists are mostly composed of mica often accompanied by crystals of staurolite, or andalusite, less commonly, by hornblende or garnet. Some layers are highly charged with pyrite

and in a few cases sillimanite was observed. The predominance of mica gives the rock a light silvery grey, shining lustre. The coarse, crystalline varieties of andalusite and staurolite schists are found mostly at the eastern end of the field, while the coarse hornblende schists are confined to the western end where they sometimes attain a great development.

In the metamorphosed zones surrounding the granite, every gradation from unaltered slates and quartzites to completely recrystallized schists and gneisses are noticeable as the granite is approached.

A slight amount of metamorphism, due to dynamic action, is also developed locally along the axes of some of the sharp folds where the rocks have suffered great compression, and this is specially noticeable in the eastern end of the field where the strata are more closely folded.

Structural Relations.

The importance of a knowledge of the structure of the Goldbearing series will be generally conceded when it is understood how intimately bound up with the geological structure is the distribution of the ore deposits. The unravelling of the structure is by no means easy. Only one horizon, the boundary between the Goldenville and Halifax formations, can be traced throughout the field, but, while in the east this boundary is sharp and distinct, in the west it is not nearly so distinct. The structure of the Goldenville formation is generally more easily deciphered than that of the Halifax in which the cleavage of the slates is often so much developed as to obliterate nearly all traces of stratification. Traverses made across the series from north to south show a succession of alternating zones of the Halifax and of the Goldenville formations varying in width from a fraction of a mile to several miles. A close study of the structure of these zones shows that the strata are closely folded in a series of long parallel anticlines and synclines, the tops of which have been extensively eroded.

In the eastern part of the field the width of the quartzite zones is generally much greater than that of the slate, while in the western part, the two formations are more nearly equal in width. In the eastern half these zones extend in a general east and west direction, while in the

western half they take a northeast and southwest direction. The slate zones of the east take in general the form of much elongated ellipses surrounded by quartzite, while in the west the zones of quartzite are mostly elliptical in shape, and they are surrounded by slate. The chief difference between the structure of the east and that of the west is that, in the east the folds are much more tightly compressed, the strata in the east commonly dipping at angles varying from 60° to 90°, while those in the west generally dip at lower angles. This is probably due to the predominance of the thick, massive and inflexible beds of quartzite in the west offering more resistance to the pressure than the alternating thinner beds of quartzites and slate beds of the east.

Along the anticlinal axes the strata lie in a series of dome-shaped folds or "domes", the axes of folding pitching alternately to the east and west. It has been thought that these domes were produced by a second series of parallel folds crossing the east and west series at a high angle. There is, however, no such alignment of the domes in the east, though in the west it does occur in some places where broad folds or undulations are found here and there having a northeast and southwest orientation, but generally only for short distances. In Queens county there is an important transverse anticlinal fold, producing a general doming of the main anticlines and an extensive development of the quartzite. The result is that the lowest known beds of the series are exposed at the surface. The compression that produced the pitching folds was probably contemporaneous with that producing the long east and west folds and generally was local in its action.

Whereas the anticlines are approximately parallel they vary in length from a few miles to 100 miles (160 km.). In some places two anticlines unite to continue as one, several subordinate crumples being formed at the place of union. In other places one anticline dies out only to be succeeded a short distance north or south by another, or it may be broken up into a series of short folds arranged en echelon the whole combining to make one great fold. Subordinate small crumples a few miles in length, on the limbs of the main anticlines are exceedingly common, particularly in the west, and more specially in the Halifax formation. In this formation the slates, on account of their more plastic nature crumpled into small folds more

readily than the quartzites. The pitching anticline of a dome of quartzite surrounded by slate also in many places divides into several crumples where it comes to the slate.

The main folds are on an average about 3 miles (4.8 km.) apart, and the domes along the different anticlines are from 10 to 20 miles (16 to 32 km.) apart. While the limbs of the anticlines dip generally at high angles and are frequently overturned, the pitch to the east or west is seldom more than 30°. At Oldham the south limb dips 70° and the north one 60°, while the pitch is west 25° and east 40°. The pitch varies greatly within short distances. At Waverley the pitch increases from 5° to 24° within 500 feet (150 m.); at Oldham it increases from 30° at the surface to 40° at a vertical depth of 900 feet (270 m.).

The Goldbearing series has suffered a great deal of faulting and the fractures may be grouped into two classes, namely, cross-country faults and local faults.

The local faults are those that are found in the separate gold districts only and do not continue for great distance along the strike nor in depth. They are closely related in origin with the doming of the anticline and are frequently found to radiate from the centre of the dome, as in the eastern part of Oldham.

The cross-country faults are those that can be traced several miles across successive folds. They form a series of breaks approximately parallel and have a northwest and southeast direction. Nearly all those in the eastern half of the field are known as left-hand faults, that is the horizontal displacement is to the left of one facing the fault from either side. Those in Kings county, on the contrary, are right-hand faults. The faults in many cases have determined the remarkably straight courses of some of the river and brooks, and the alignment of swales and numerous cold water springs. The most important faults are found in the eastern end of the field. Some have been traced the whole width of the series and their horizontal displacement along the strike varies from a mile and a half to a fraction of a mile. The numerous faults of Kings county have a horizontal displacement varying from a few feet up to 900 feet (275 m.).

In addition to the folding and faulting produced in the rocks, other phenomena such as brecciation, cleavage, jointing and fissuring have resulted from the forces to which they were subjected. It seems probable that the innumerable

quartz veins lying in the stratification planes on the domes had their origin in the deposition of quartz in fissures produced by the close folding and the consequent slight slipping of the strata upon one another. The fissures in which cross-veins were deposited, are also probably due to movements but, unlike those in which the interbedded veins were deposited, are quite local. A few cross-veins lie in fault planes of greater magnitude.

Cleavage is well developed throughout the field. In some places and more especially in the vicinity of sharply folded anticlines and synclines, the quartzite is squeezed into quartz-schist and the slate into mica-schist. The planes of cleavage are parallel with the axis of the folds, and are highly inclined, often only several degrees from the vertical. It is a noteworthy fact that in the vicinity of an anticline the planes of cleavage dip towards the centre of the fold. In those slate beds carrying quartz veins the cleavage plane is frequently found to curve aside on approaching the crest of a corrugation. Distinct serrations are frequently found along bedding planes and are due to motion along the cleavage plane, and it may be that some of the small crenulations found in the quartz veins are due to the same cause.

At the apex of the anticlines the thickness of the beds of slate of the Goldenville formation is often much greater than on the limbs. As folding proceeded there was some sliding of the beds upon one another, pressure at the apex of the folds was somewhat relieved, and the slate being more plastic than the quartzite was squeezed from the limbs to the apex. In some places the pressure was great enough to force all the slate aside and bring the beds of quartzite together. The compression of the beds on the limbs of the folds must have had the effect of diminishing considerably the original thickness of the sediments. In calculating the thickness of the series, this compression was not taken into account, so it is reasonable to suppose that the original thickness must have been much greater than that measured, but how much greater it is difficult to estimate.

Age.

The Goldbearing series has been referred by different writers at different times to various ages from Pre-Cambrian to Ordovician. Although a Lower Cambrian age has been

most generally applied to the series for a number of years the weight of evidence seems to point to an earlier origin, probably Pre-Cambrian. Certain markings or forms have been discovered from time to time and by some students have been thought to indicate an organic origin but these have in many cases turned out to be nothing more than concretions, or their organic origin has been disputed, and none have been characteristic enough to be of any determinating values. Of the contiguous formations, the oldest seems to be a series of fossiliferous rocks in Annapolis and Digby counties ascribed to the Silurian or early Devonian. In determining the age of the Goldbearing series therefore, lithological resemblances and analogies with distant formations have had to be resorted to, but, although suggestive, they can hardly be regarded as absolutely determinative.

Dawson [**2**] and Hind first considered the series as probably Ordovician. Later Selwyn pointed to their resemblance to the Lower Cambrian and Lingula flag series of North Wales, and still later, Dawson [**2**] believed the series to be Cambrian. Different authors have pointed out the resemblance existing between the Goldbearing series of Nova Scotia and the Pre-Cambrian slates and quartzites of the Avalon peninsula of Newfoundland. Murray as early as 1868 advanced the opinion that the resemblance "is too striking and marked to be overlooked, and the inference is that on further inquiry they will prove to be of the same age." Walcott, Van Hise, and Matthew also hold the same views.

In a study of that area lying south of Wolfville and Kentville, Kings county, Faribault (1908) has shown that, with the exception of the Silurian strata of New Canaan, all the rocks appear to be conformable and to belong to the Goldbearing series, and to include the fawn slates in which *Dictyonema websteri* was found at the same horizon at different points.

Thus the problem still remains to be solved; and, until more conclusive evidence is obtained the series may be regarded as most probably Pre-Cambrian.

GRANITE INTRUSIVES.

Granite is distributed widely throughout the series in the form of batholiths, the largest of which extends from the coast at Halifax westward in the form of a crescent, nearly

to the western end of the province, dividing the sedimentary series into two parts, an eastern and a western. In the eastern part of the field, some of the batholiths are also quite extensive in area, others assume the form of parallel bands a fraction of a mile wide and several miles long, cutting the sedimentary rocks at slight angles. At Liverpool bay, large granite dykes occur that also have a tendency to follow the stratification planes.

The composition and texture of the granite vary much with the locality and mode of occurrence. The rock consists for the most part of a light-grey or reddish-grey, coarse, porphyritic, biotite-granite, generally studded with large phenocrysts of white or pink-white feldspar. In the west, a light pearl-grey or pinkish-white, fine-grained, muscovite-granite occupies small areas penetrating the biotite-granite as well as the sediments. With the muscovite-granite are associated dykes of coarse pegmatite often passing to quartz, and bearing a large variety of minerals.

The granite is found everywhere to cut and penetrate the sediments; it cuts also the anticlinal and synclinal folds, and the interbedded quartz veins, without affecting in the least their original structure. In the vicinity of the granite the clastic rocks have been metamorphosed into gneisses and schists, the degree of metamorphism being greatest near the granite. The line of contact is sometimes sharply defined, but generally there is apparently a gradual transition from slate and quartzite to granite which in many cases is such as to suggest the assimilation of the intruded rocks by the large subjacent igneous masses. Within the granite areas are included large and small insular patches of altered sediments whose original structure is apparently not disturbed, and the granite itself often contains numerous small inclusions of sedimentary rock partially absorbed.

The granite intrusion took place during the Devonian period; it affected the Nictaux-Torbrook rocks which are placed at the base of the Devonian and it is on the other hand overlain unconformably by the Horton series which has been referred by some writers to late Devonian and by others to Lower Carboniferous.

BASIC INTRUSIVES.

Basic intrusions, taking the forms of dykes and sills, are found cutting the sediments, but they are confined almost wholly to the western part of the field. In Kings

county, on the northern margin of the series, these intrusions are numerous. They vary in thickness from a few inches to 100 feet (30 m.) or more, and nearly all lie in the bedding planes of highly inclined strata. A dyke of rusty weathering diabase, 100 to 900 feet (30 to 275 m.) thick, has been traced along the shore in Queens and Lunenburg counties for over 25 miles (40 km.). This intrusion has altered the sediments and impregnated them with magnetite for a few inches on each side.

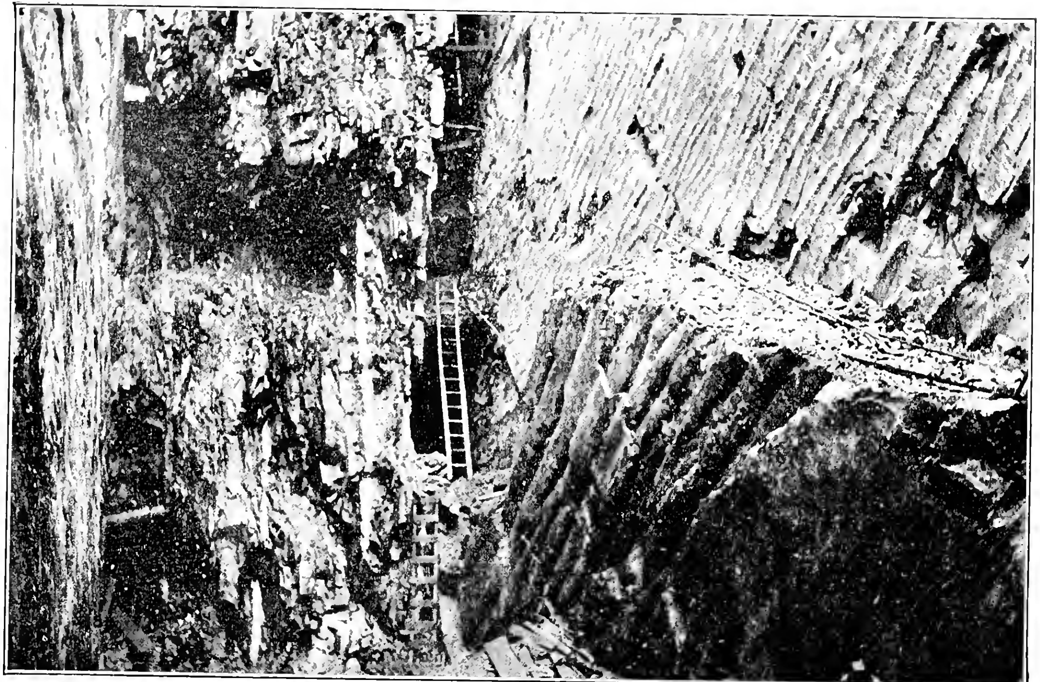
The basic rocks are generally dark greenish, diabase or diorite, and have undergone much alteration and in the case of the narrower bodies, have become quite schistose. Those of Kings county are probably roughly contemporaneous with the folding but older than the faults crossing the series, showing that they are of a great age. Like the granite they are probably Devonian but the relation of the two intrusive rocks has not yet been exactly determined.

THE GOLD DEPOSITS.

General Character and Distribution.

The gold deposits are the only deposits of the area that are of any considerable economic importance. These nearly all occur in quartz veins, but a small amount of gold has been recovered from detritus. The deposits of auriferous antimony ore occurring in cross-country veins in the Halifax formation at West Gore have been worked considerably for antimony and gold.

The gold-bearing quartz has been reported as occurring in the granite, but the authenticity of the reports may be regarded with suspicion. With this possible exception, all the known veins occur in the sedimentary strata of the Goldbearing series. Although there are a few important veins that cut across the stratification, most of the auriferous quartz veins are of the interbedded type. They occur chiefly in the beds of slate which are found interstratified with the beds of quartzite throughout the whole thickness of the Goldenville formation, and their distribution and structure are to a great extent the result of the action of dynamic forces to which the enclosing rocks were subjected. The interbedded veins are found in great numbers, aggregated in groups on the domes along



Corrugated hanging-wall of quartzite and section of quartzite and slate beds, with intercalated veins, on south side of the anticlinal dome. Mount Uniacke. N.S., 1909.

the anticlines; and in some few cases on the pitching portion of the anticlines. Rarely they are formed in the synclinal troughs. The domes thus determine the location of nearly all the groups of veins and each of them may be considered as an independent gold district. Some domes however, especially in the west, do not show the presence of quartz veins, but this appearance may be simply due to the concealment of the bedrock by drift.

A tabulation made of the principal anticlines with the gold districts located on them, from the map-sheets published by the Geological Survey, shows that to the east of Halifax 33 gold districts are distributed along 14 anticlines in an area 40 miles (65 km.) in width by 100 miles (160 km.) in length.

The gold-bearing districts are much less numerous and generally less productive in the western part of the field than in the east. This is chiefly due to the folding being more gentle and the domes broader, hence the slipping of the beds and fracturing has been less pronounced with the consequent failure to produce channels favourable for the circulation of solutions and the deposition of vein matter.

Quartz, with hardly an exception, forms by far the largest proportion of the vein filling, but occasionally inclusions of country rock or certain minerals are quite abundant. Associated with the quartz, the principal minerals are pyrite, arsenopyrite, calcite and galena, less frequently chalcopyrite, sphalerite, dolomite, chlorite and pyrrhotite, and more rarely scheelite, stibnite, feldspar, rutile and specular iron.

Silver is found in the gold recovered from cross-veins at Leipsigate, Brookfield, and some other districts, sometimes in such amounts as to reduce the value of the product to $16 an ounce. But the gold produced from the interbedded veins is generally very fine and varies in value from $19 to $20 per ounce. The gold generally occurs free and visible and is amenable to amalgamation, but it is also in part intimately bound up with the sulphides, thus requiring other methods of treatment for its recovery. In the white, coarsely crystalline quartz it is found in coarse, visible particles, while in the bluish, oily quartz of the laminated veins it is usually disseminated more finely or is found in plates in the layers parallel to the walls. It is generally most abundant on the footwall, is very

commonly associated with arsenopyrite, frequently in lenses or nodules forming large nuggets, and almost invariably with galena. Small crystals of gold are sometimes found in rhombic dodecahedra and octahedra, generally distorted, with bevelled edges and finely striated surfaces. Plates and scales are often found in the adjacent slate, but close examination always reveals the presence of minute films or threads of quartz traceable to the parent vein.

Interbedded Veins.

As has already been pointed out the auriferous veins are found on domes, although in some few cases, as at the Richardson mine, they are found on the pitching parts of anticlines remote from domes. In such cases, however, conditions favourable for ore deposition have been brought about by a notable change in the angle of pitch, producing virtually a doming of the anticline that is not apparent at the surface.

The distribution of the veins on any particular dome is intimately related to the rock structure, and complexity is introduced by the unsymmetrical character of the domes. On sharp, closely folded anticlines, where the two limbs form an angle of less than 40° or 50°, the veins are found close to the apex and curve over the anticline forming a succession of superimposed saddles, similar to the "saddle-reefs" of Victoria, Australia. On broad folds, on the other hand, where the angle formed by the two limbs is over 45°, the veins are found at a greater distance from the axis, but generally within the limit of curvature of the strata of the fold beyond which the dip ceases to increase and becomes uniform. If one end of a dome is flatter than the other, the veins at that end are further removed from the axis than at the other; and if veins occur on both limbs of a transversely unsymmetrical dome those on the limb with the higher angle of dip will be nearer the axis and more abundant than those on the limb with the lower dip. In many districts, the veins are found on one limb only and then they invariably occur on the limb with the higher dip, which is generally the south dip.

The interbedded veins have a more or less crescentic outcrop. On the sides of long domes, they form nearly straight lines, but finally curve with the strata around the

apex of the fold, and some have been traced continuously around the end of the dome from one limb to the other. But generally, the outcrops of veins form only small portions of elliptical curves, and these are most frequently arranged *en echelon* so that they lie in zones radiating from the centre of the dome and diverging more or less from the major axis according as the fold is broad or narrow. These zones are on those parts of the dome where the strata do not strike approximately parallel with the axis of the fold but curve towards the axial line. In symmetrical domes, like that of Oldham, there may thus be four zones, and these four zones may be considered as merging into one another so as to favour the formation of veins, the outcrops of which form almost complete ellipses. In most districts, however, there are only two zones of veins, as at Waverley where they may be regarded as merging into one to form saddles; and in some districts there is only one zone, as at South Uniacke.

In some districts the formation of veins seems to have been dependent on small subordinate folds or flexures. In some places there is a curving of the main axis of the fold and in such cases veins are found to be much more numerous and auriferous on the convex side of the axis. In some domes there is a torsion or twisting of the fold adding to the complexity of the structure and occurrence of the veins.

Mining operations in several districts have shown that underlying the veins exposed at the surface are other parallel interbedded veins. Each district has thus a vein-bearing zone with a horizontal extent determined by the outcropping veins and with an indefinite vertical extent. In its vertical extension each zone is believed to be roughly parallel with the axial plane of the anticline. The distance of the exposed veins from the axis depends on the dip of the strata, and it is probable that the distance from the axial plane of any portion of the zone of veins extending into the earth is also dependent on the dip; if the fold gets sharper with depth, the zone of quartz veins probably approaches the axial plane, or if it flattens with depth, the zone of auriferous veins recedes from the axial plane.

Most of the veins lie in slate beds varying in width from a fraction of a foot to a few feet. Rarely they lie in the middle of the bed and, as a rule, only when the bedding is marked by some difference in composition or texture,

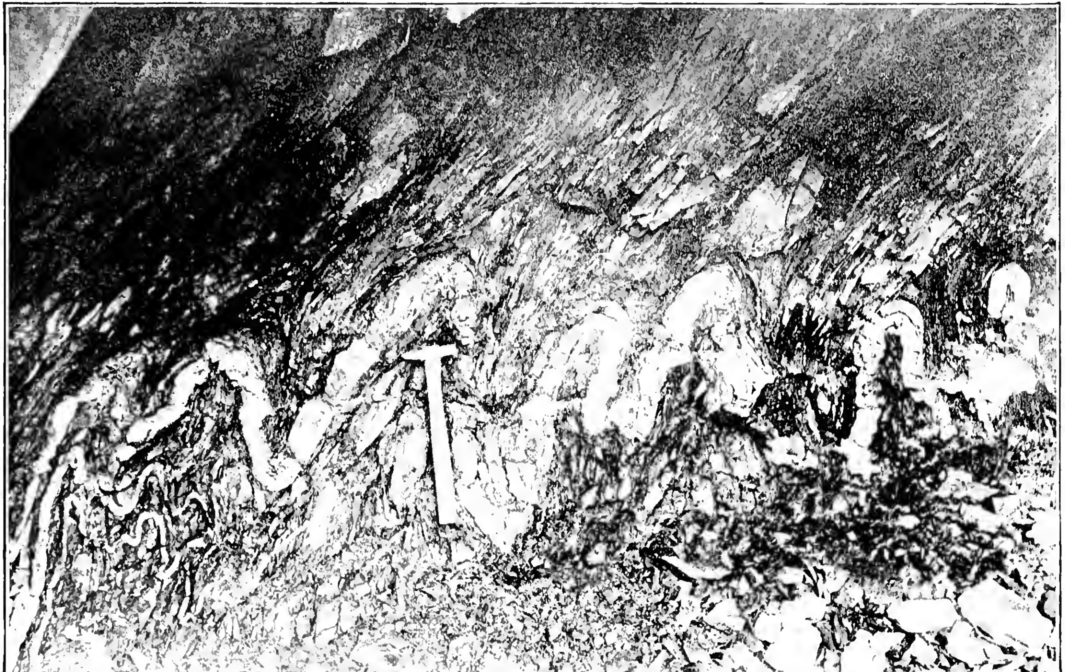
producing planes along which fracturing took place. By far the greater number lie on the foot-wall with only a thin film of crushed slate or gouge separating them from the quartzite. Occasionally, the quartz is "frozen" to the wall.

As a rule the veins are quite conformable with the strata, but occasionally they pass from one wall to the other. A saddle-vein may have one leg on the footwall and the other one on the hangingwall. On a small crumple, the vein may lie on the footwall of that part above the crumple and on the hanging wall in that part below, forming irregularly shaped veinlets and quartz masses scattered all through the slate belt where it passes from one wall to the other in the short limb of the crumple. Some veins bifurcate, and one portion passes to the hanging wall, while the other remains on the footwall.

Some slate beds are found to carry several quartz veins, generally conformable with the strata, and constitute those large bodies of low grade ore, often 5 to 20 feet (1·5 to 6 m.) thick, that have of late years been worked with profit. These deposits are designated "belts", while the well-defined vein is designated a "lode" or "lead". The belt is sometimes also composed of a network of veins, the veinlets following the bedding planes for short distances and then crossing obliquely to join other veinlets.

Corrugated Veins.

Interstratified veins often exhibit a remarkable folded or corrugated structure within the beds of slate that contain them. The corrugations, or crenulations, usually occur at or near the apex of the anticline and sometimes in the syncline, and run parallel with one another and in a direction approximately parallel with the axis of the fold. At the apex of the fold, the corrugations dip with the dip of the strata, which then corresponds to the pitch of the fold, but on each side of the apex they radiate more or less from the centre. The amplitude and interval of the folds generally vary with the thickness of the vein and of the enclosing bed of slate. Also the nearer the veins lie to the anticlinal axis, the more pronounced these corrugations become. In some veins the folding has been so intense as to separate the quartz with disconnected rolled portions. The name "barrel" quartz has been given to the larger corrugations,



Serpent vein crumples between beds of quartzite above and slate below on the western plunge of anticlinal dome. Tourquoy mine, Moose River, N.S.

because when such a corrugated deposit was first uncovered at Waverley, it looked to the miner like the back or top of barrels lying in rows.

The slates beds adjacent to the corrugated veins show a sympathetic folding which extends for a few inches to a foot or two from the vein and gradually dies out. Seldom is the influence felt in the quartzite beds ,and then only in connection with the larger corrugations on the apex of an anticline.

Where one of the corrugations becomes enlarged or some part of a vein swells out and takes on some peculiar form extending for some distance in one direction, this portion of the veins is called a "roll". A roll is generally richer than other parts of the vein. Its position is usually dependent on some peculiarity of rock structure such as some small subordinate crumple, some slight flexure in the beds indicating an incipient crumpling or some zone of fracturing. As such structures usually affect a great thickness of strata, a number of veins is affected by similar conditions and a roll in one vein is succeeded by similar rolls in the underlying or overlying veins. Series of such rolls are found in most districts and constitute one of the principal and more persistent forms of ore deposits.

Thickness of Interbedded Veins.

The thickness of the interbedded veins varies from a fraction of an inch to 20 feet (6 m.). The greater number may not be over an inch, (25 cm.) but those that have been worked, generally vary from 3 to 18 inches, (7 to 45 cm.). The largest veins are usually found on sharp anticlines in the shape of saddle veins. Saddle veins attain their maximum thickness at the apex of the fold and become thinner as they extend down on the limbs. Thus the Richardson saddle vein while 20 feet (6 m.), thick at the apex thinned down to 6 feet (1.8 m.) at the 300-foot level. Some leads have been followed in depth several hundred feet with little or no decrease in size, but others have been found to pinch to a mere film and it is probable that nearly all of them pinch out at no great depth. The Dominion lead at Waverley was found to decrease from 15 inches (40 cm.) on the surface to a mere film of quartz with small lenticular pockets at 500 feet (150 m.) and to be completely wanting at 600 feet (180 m.)..

Veins are frequently thickened by local disturbances, such as a bend, a crumple or a faulting of the strata.

Although leads show a great similarity and are very numerous, yet many of them possess a certain individuality, some peculiarity of colour, structure, lamination, distribution of sulphides, quantity or form of gold, serving to distinguish them from others of the same district.

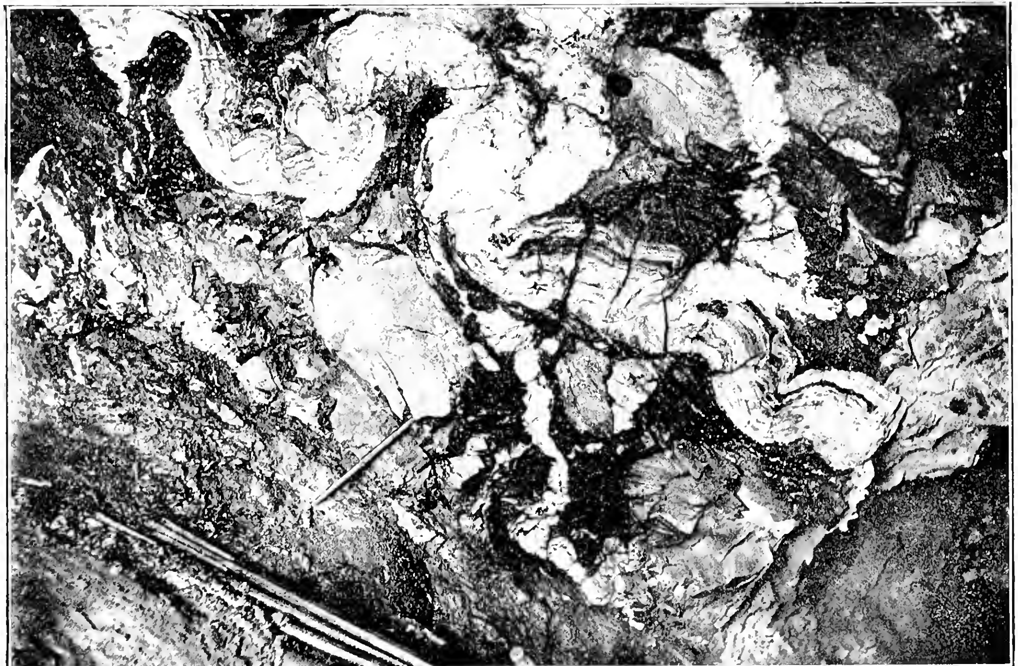
Cross or Fissure Veins.

A few important veins cut across the strata for a considerable distance, and in some districts they form the principal auriferous deposits. These cross veins, often spoken of as fissures, sometimes curve and branch, contain inclusions of country rock, and have a gouge on the walls. All the most important are found on domes, generally cutting the main anticline at various angles. They occur chiefly in the Goldenville formation, but also in the Halifax formation, especially at the base. Seldom does a cross vein lie in the fault plane. In the case of the Cope lode of Central Rawdon and the Baker vein of Oldham, which are exceptions to this rule, the faults are probably younger than the veins.

The thickness of the cross veins is less regular than that of the interbedded veins, probably because they generally intersect alternating beds of different hardness. They do not attain great thickness, except sometimes at their intersection with interstratified leads, flexures or rolls. The mineral content is generally the same as that of the interbedded veins, but the laminated structure is wanting. In many cases the value of the gold extracted is much reduced by the presence of silver. At West Gore enough stibnite was found to form gold-antimony ore deposits of considerable value and extent.

Bull Veins.

There is another kind of vein differing much from those already described. It may cross the strata or roughly lie in a stratification plane. It shows little or no trace of lamination, carries few metallic minerals and is composed of white crystalline quartz in which geodes with quartz crystals are sometimes found. These veins are usually thicker than the others, varying from one to several feet. They are not auriferous and are known as bull veins.



North leg of the Richardson saddle-vein at a depth of 400 feet, showing banded and corrugated structure, with angulars entering from below and leaving above. Richardson mine, Isaac's Harbour, N.S., 1905.

Angulars.

Many of the main veins have branches passing into the foot or hanging wall. These branches are termed angulars, and they play an important part in the ore deposition in certain veins. The point from which an angular passes from the main vein into the hanging wall is usually higher than that from which it passes into the footwall, and the intervening portion of the vein is frequently thicker and richer than other portions. Their distribution and attitude is dependent on the structure of the dome. In some parts of a dome they may be numerous or completely absent; they may have a general strike and dip quite different from what is found in another part of the dome. In crossing the bedding, they generally run nearly perpendicularly to the quartzite but obliquely through the slate. In a closely folded anticline they are more numerous at or near the apex, where they often form a reticulated system of veins extending along the axial plane from one lode to an overlying or underlying one.

The quartz of the angulars differ from that of the main veins in being of a fine, granular texture, free from laminations.

ORE DISTRIBUTION.

All the veins are not auriferous. The coarsely crystalline quartz seldom carries gold, while the laminated veins of oily quartz-bearing sulphides, generally do. In a few auriferous veins the gold seems to have had a fairly uniform distribution, but experience has shown that in most of them there was more or less segregation into pockets and shoots.

Some of the richest ore mined has been found in pockets. In the Blackie lead at Oldham the gold was found aggregated chiefly in nodules of arsenopyrite; and in the Hay lead lying 1,800 feet (548 m.) north of the anticline of the same district, an isolated pocket carrying 60 ounces of gold was found at the intersection of an angular with the main lead.

The great proportion of the ore, however, lies in shoots having more or less definite boundaries and directions. They vary from 20 to 60 feet (6 to 18 m.) or more in breadth and are frequently accompanied by a thickening of the vein. In interstratified veins, many shoots have

Lake lode ore-shoot in Halifax slate formation at a vertical depth of 1000 feet.
Caribou, N.S., 1904.

been worked to a vertical depth of 300 and 400 feet (90 to 120 m.). A shoot on the Hard lead, South Uniacke, was followed 1,200 feet (360 m.) on a dip of 28° east; while that in the Sterling Barrel lead, Oldham, has been worked to a depth of 1,610 feet (487 m.) on a dip varying from 30° at the surface to 43° at a vertical depth of 900 feet (275 m.), and in 1909, the ore averaged 2·88 ounces per ton. The latter is the deepest mine on an interbedded vein.

Several shoots in cross veins have also been mined to a vertical depth of 200 and 400 feet (60 and 120 m.), and two, to a vertical depth of 1,000 feet (300 m.); one of these was worked throughout a length of 2,000 feet (610 m.).

As a rule, ore-shoots occur in the rolls that have been already described, that is those parts of the veins in which there is some irregularity in size, form, structure or composition.

The interbedded leads are frequently found to be very rich at their intersection with angulars as well as in the thickened parts lying between the lines of intersection with angulars from below and above. All angulars do not enrich the leads they cut, and frequently only a set coming from some one particular direction have favoured the enrichment of the leads. The angulars themselves are usually not auriferous, but some have proved gold-bearing, especially in those parts where they cut obliquely across slate beds.

There is much irregularity in the distribution of the ore in belts; in some, all the veins are auriferous, in some, only one, and in others, one vein will be auriferous for some depth, then becomes barren and an adjacent one becomes auriferous.

That there is some order in the distribution of the ore-shoots was pointed out by Poole as early as 1878. A study of the plans made by Faribault of the different gold districts, reveals an alignment or arrangement of the outcroppings of the ore-shoots in nearly every district. In the case of sharply folded anticlines, the line of ore-shoots runs roughly parallel with the axis or diverges slightly from it, radiating from the centre of the dome, while in broad folds the line diverges still more from the axis. The shoots pitch in the general direction of the pitch of the anticline and at about the same or a little higher angle.

In some veins two or more parallel shoots have been found. The ore-shoot on the Hard lead, South Uniacke, really consists of two streaks lying 40 feet (12 m.) apart; in the Mulgrave lead, Isaacs Harbour, a shoot 30 feet (9·1 m.) broad lay 180 feet (54·7 m.) below another 12 feet (3·6 m.) broad, both pitching west at an angle of 12°.

The distribution of the shoots is frequently dependent on some subordinate flexure or crumple in the strata. For example, the large series of ore bodies worked at Renfrew is due to a subordinate undulation in the strata on the south limb of the dome. In this regard each district has its individuality, the structure of one dome never being just the same as that of another. The distribution of the ore-shoots, consequently, is never exactly the same in any two districts.

In cross veins the ore body is found, in some cases at least, to lie at the intersection of the vein with certain strata or main leads. At Cow Bay, the ore body dips south at the same angle as the strata and follows certain beds at the base of the Halifax formation highly charged with pyrrhotite. The shoot, followed 2,000 feet (610 m.) in the Libbey vein, extended from its intersection with the Mill lead on the north to the vicinity of its intersection with the Jim lead on the south.

PAY ZONE.

Certain facts point to the existence in most districts of zones extending to a considerable depth in which a succession of auriferous, interbedded, quartz veins of similar character and extent lie superimposed one above the other. On the north limb of the anticline at Goldenville several parallel veins lying close together pass under one another, and each has been worked to some depth beneath the overlying veins. An example of superimposed saddle-shape ore bodies on the apex of the anticline is found at Isaac Harbour where the workings of the Burke lead was carried below those of the Archie, McPherson and Saddle leads. So also at Mount Uniacke, a series of ore-shoots was worked on the West Lake, Nuggety, Little and Borden leads where they are affected at successively greater depths by a subordinate crumple with an axial plane dipping north at a high angle.

The observation of these and numerous other relations led the writer to the propounding of the "pay-zone" theory* As has been pointed out the distribution of ore-shoots is dependent on the structure of the anticlinal fold or subordinate flexures on the fold: they lie in a line passing through similarly curved or twisted portions of the strata that during the folding process were subjected to pressures and tensions and were fractured so as to permit the transmission and deposition of minerals. The subordinate flexures and peculiarities of structure, on which the distribution of ore-shoots depends, extend to an unknown depth, and it is claimed that interbedded veins and ore-shoots should succeed one another with depth so long as the same structural conditions continue as at the surface. These structural conditions generally extend in depth parallel to the axial plane of the dome. We thus get a pay-zone the surface extent of which coincides with the surface over which the ore-shoots outcrop and which extends parallel with the axial plane of the dome to an indefinite depth.

The evidences in favour of the theory are the fact that gold mining has been carried on in the province to a vertical depth of 1,000 feet (300 m.) in fissure veins and 900 feet (275 m.) in one interbedded vein; that pay-ore is not limited to any particular horizon, but has been mined throughout the whole thickness of the Goldenville formation; and the analogy existing between the interbedded veins of Nova Scotia and the saddle-reefs of Bendigo, which have been worked successfully to a depth of over 3,000 feet (900 m.) and proved auriferous at over 5,000 feet (1,525 m.).

While the hypothesis may be of general application it is not claimed that it will hold in all particular cases. Structural features vary with depth; subordinate folds may not persist and main folds may flatten and thus the pay-zone may die out or be shifted in position with regard to the anticlinal axis. For example, in the case of the Dufferin mine, rich ore was found at the apex of the fold at the surface, but in the underlying veins owing to the flattering of the dome it was more remote from it.

*Geol. Surv. Can., Vol. V. p. 57 A. A. and Vol. X. p. 108 A.

Genesis.

Some of the earlier investigators such as Hind and Hunt, maintained that the interstratified veins are syngenetic, that is, were formed contemporaneously with the containing rocks, but later students of the Nova Scotia gold fields are thoroughly convinced that they are epigenetic, i.e., deposited subsequently. That the cross-veins are of later origin all are agreed.

Campbell, the pioneer in the gold fields of the province, expressed the opinion that the veins were of later origin than the rocks, and Selwyn and Poole were strong supporters of his theory. The opinion that prevails to-day is that the veins were formed during the folding of the rocks, in the openings produced by the movements of the strata. During the folding of the interstratified beds of slate and quartzite, or shale and sandstone, there was a certain amount of slipping of one bed over another. This slipping produced openings along the bedding planes, which were in general widest at the apex of the folds, and decreased in width with depth along the limb until at a depth of a few hundred feet they pinched out. During or subsequently to the formation of these openings, which took place within the less resistent beds, the vein filling was introduced by solutions. Thus is explained the dependance of vein distribution on rock structure.

The arching of the rocks on closely folded symmetrical domes produced fissures passing over the apex and down each limb; on broad domes the arches were not strong enough to sustain themselves and the fissures were formed only on the limbs; on unsymmetrical domes the slipping of the strata was such as to produce fissuring along the bedding planes of the limb with the higher angle of dip; and subordinate flexures, in which the strata were given a curve of less radius than ordinary, were especially favourable to the production of fissures.

The process of folding was long continued and the deposition of vein matter probably took place during the process. Small fissures were formed along the bedding planes and filled with quartz only to be followed by other parallel openings between the quartz sheet and the slate and further precipitation of quartz in the new openings. Films of slate adhering to the quartz forming the wall of the new fissure thus became embedded in the vein. A succession

Anticlinal portion of the Borden vein on a subordinate fold corrugated in slate between beds of quartzite. West Lake mine; Mount Uniacke, N.S.

of such events produced the laminated character of the interstratified veins. It is also probable that in many cases the quartz was deposited in the slate along a number of parallel planes lying close together in an area of minimum pressure and that the quartz films increased in thickness through a widening of the spaces either by the folding of the strata or by metasomatic replacement.

The origin of the corrugations is more difficult of explanation. That they are dependent on the rock folding is generally conceded and the following explanation has been adduced:—Many veins were formed long before the folding process was completed and during the subsequent stages they were subjected to the same forces as the rocks. The main forces that produced the folding were horizontal, and if the horizontal forces be resolved into components perpendicular to and tangent to the bedding plane, the component perpendicular to the bed will be greater on the limb than at or near the apex of the anticline. There will thus be a tendency towards a thinning of the beds on the limbs and a proportionate thickening at and near the apex. This will express itself in a motion of the more plastic beds, that is of the shales or slates, from the limbs towards the apex resulting in a thickening on the latter, a phenomenon that is frequently observed especially in closely folded strata. Any quartz vein already formed in such slate will partake of the same lateral motion; on the limbs of the fold where the strata are not curved they will suffer little change, but where the strata begin to curve and the slate beds to thicken, the veins will begin to fold and produce corrugations. On the side of long domes there was but one deforming force that came prominently into play, that which produced the east and west folding, and the corrugations are consequently horizontal and parallel to the axis; but at the pitch of the dome a second force about at right angles to the first expressed itself in the pitching of the dome, the resulting movement was more complex, and corrugation was produced radiating more or less from the centre of the dome.

This theory of the origin of corrugations would also account for the different degree of crenulation often exhibited by different veins intercalated between the beds composing one single slate belt; the more corrugated veins being generally older than less corrugated ones. The quartz appears to have become plastic under the enormous

North lode at the 200-foot level, 20 feet above the syncline of a subordinate fold, made up of angulars entering from the foot-wall along the cleavage plane.
Dufferin mine, N.S., 1904.

pressure, and the deformation may have been effected by the slow flowing of particle over particle. The change in form may, however, have been brought about by the slow process of solution and reprecipitation ; if this be so it would indicate the existence of slow folding processes extending over a long period of time. The contorted broken quartz of some belts suggests that in some places the motion was too rapid to admit of the veins maintaining their continuity either by flow or by solution and reprecipitation.

The origin of some of the small crenulations which are often observed in many interstratified veins and in a few cross veins having a thickness less than one inch, is probably due to a slight motion along the numerous cleavage planes during the folding process at stages subsequent to the deposition of the veins, for these crenulations are often found to coincide with the intersection of the cleavage with the bedding plane. It is also possible that some of the larger corrugations are the result of the combined motion of the slate beds from the limbs towards the apex and that of the wall-rock along the cleavage planes.

The bulk of the evidence shows that the veins were filled by ascending solutions of a deep-seated origin. These found a passage upward through the fractured portions of the domes. A fracturing across the bedding as well as fissuring along the bedding planes seems to have been necessary for the formation of veins and ore deposits: veins are not commonly found along straight non-pitching anticlines although there was, no doubt, a great deal of fissuring along the bedding planes; on the other hand, where the anticlines pitch and the rocks were fractured across the bedding, veins are abundant. The cross fractures are themselves filled with quartz forming the angulars entering and leaving the interbedded veins. The cross fractures seem therefore, to have provided channels for the passage of solutions across the beds of quartzite and slate to the interbedded fissures along which deposition took place. That the solutions entered by way of the angulars is borne out by the fact that the rich portions of interbedded veins are those portions lying between the line of entrance of an angular and the line along which it leaves the main lead.

The source of the ascending solutions is not known, but it is held not to be in the granite or any other known igneous intrusion. Field evidence goes to show that the

granite intrusion was later than the formation of the veins. At different places, interbedded veins are cut across and sometimes along their courses, by dykes of granite, and the proximity of the intrusion appears to have had no effect on the size or richness of the veins.

Another evidence that the veins were formed prior to the granite intrusion is the complete absence of any disturbance or irregularity of the structures of the anticlinal folds and more especially of the domes at granite contacts. This proves that the granite intrusion took place at a time when the folding and doming of the quartzite and slate, as well as the deposition of the veins resulting thereof, were completed, otherwise the movements and slipping of the beds which produced them would be manifested by disturbances or faults along the line of the granite contact. At Mooseland, on the western end of the dome, interbedded quartz veins have been traced continuously to the granite, without increase in size or other irregularity of structure, but they gradually become more crystalline and finally disappear at the contact where they are apparently absorbed by the granite, like the containing metamorphosed quartzite and slate.

The observations of Prest in the western part of the province give still further evidence leading to the same conclusion. He reports that at Bear River no disturbance was observed in the structure of the Nictaux-Torbrook rocks at the granite contact, and as these rocks are conformably folded with the Goldbearing rocks, he concludes also that the folding partaken of by both series must have been nearly complete before the granite intrusion; and further, as the Nictaux-Torbrook rocks are Oriskany, the folding and the quartz veins of the Goldbearing rocks would be later than Oriskany. Then, as the granite intrusion was earlier than the Horton series, which is referable to late Devonian or Lower Carboniferous, the folding and the deposition of the quartz must have taken place during Devonian time, but earlier than the granite intrusion. Finally, at Gay's river a conglomerate of Lower Carboniferous age, largely made up of fragments eroded from the Goldbearing slate, has been mined for gold. The deposition of the gold in the Goldbearing rocks must then have commenced before the Carboniferous that is to say, during Devonian time.

It is probable that small additional layers of quartz and some gold may have been added to the gold-bearing leads, during and after the granite intrusion but, so far as known, this has not been proved by observation in the field.

Little study has been given to the cause of the precipitation of the metallic contents of the veins. The ascending thermal solutions were no doubt subjected to different chemical and physical conditions, but it is difficult to surmise what these were and what has been their effect. Some factors that may have entered in the problem are, (1) decrease of pressure that the solutions underwent on entering the fissure, (2) lowering of temperature, (3) effect of other solutions originating from below or from the earth's surface, and (4) effect of certain solid contents in the rocks. Certain slates apparently exercised a greater precipitating effect than others. These are generally black and are frequently impregnated with arsenopyrite, pyrite or pyrrhotite, and the interstratified veins that can be worked with profit are usually found in beds of this character. In some cases the cross veins also are found to be enriched where they lie in contact with strata of this class.

The question of secondary enrichment has received little study and little is known with regard to what extent the fracture zones of the districts have afforded means for the passage of meteoric waters and a secondary redistribution of the mineral contents of the veins.

Briefly stated, the observed facts seem to be best explained on the theory that the veins are epigenetic, that they were formed by the deposition of quartz, sulphides and gold in cross fractures and interbedded openings occurring chiefly in the black or pyritous slate beds of the Goldenville formation, that the conditons necessary for the formation of the veins were a great deal of fracturing across the bedding planes, permitting the passage of ascending thermal solutions and that these fractures were produced where the two horizontal orogenic forces manifested themselves in the formation of domes or the pitching of the anticlines.

PRODUCTION.

Gold was discovered in Nova Scotia in 1860, and mining operations then commenced. Two years after the discovery, gold valued at nearly $142,000 was recovered from

the quartz veins, and since that time the annual production has, with the exception of three years, fluctuated between $200,000 and $628,000, nearly attaining the latter figure in 1902.

The total production of gold in Nova Scotia from 1862 to 1912 inclusive, was 936,499 ounces recovered from 2,117,639 tons of ore mined, this productiom having a value (at $19.00 per ounce) of $17,793,481, equalling an average recovery of $8.40 per ton of ore crushed.

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OLDHAM GOLD DISTRICT.*

(E. R. Faribault.)

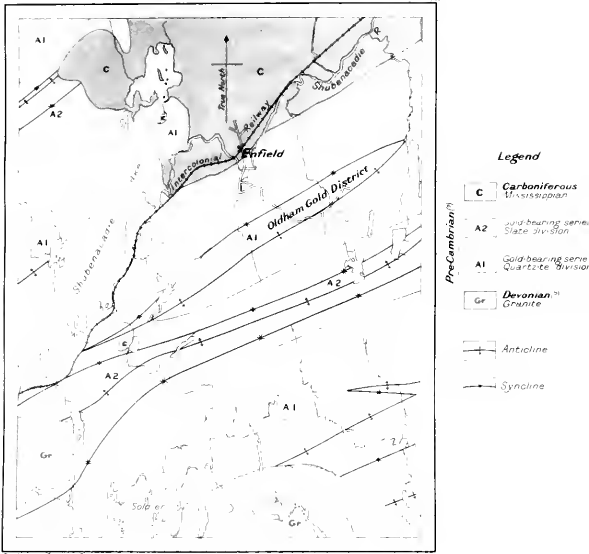
INTRODUCTION.

LOCATION.

Oldham gold district is situated in the northern part of Halifax county about 25 miles (40 km.) north of the city of Halifax and 3 miles (4·8 km.) southeast of Enfield, a small station on the Intercolonial railway. The district lies near the summit of the watershed that separates the streams flowing south through Porters lakes into the Atlantic from those whose waters reach the Bay of Fundy

* See Map—Oldham Gold District and Vicinity.

A1.



Geological Survey Canada

Oldham Gold District and Vicinity

Miles

Kilometres

by the Shubenacadie river. The altitude of the centre of the district is 317 feet (96·6 m.).

GEOLOGY.

The quartzites and slates constituting the Goldenville formation of the Goldbearing series (Pre-Cambrian) are here exposed in a subordinate anticline 9 miles (14·5 km.) long lying on the south limb of the Shubenacadie - Grand lake anticline. The distance between the two anticlines is a little over two miles (3·2 km.) and the intervening syncline lies half a mile (0·8 km.) north of the Oldham anticline.

The fold which follows a ridge running east and west is transversely symmetrical, the strata dip on both limbs at angles varying from 50° to 75°, and the axial plane is nearly vertical. The fold pitches to the east at angles increasing to 45°, but two miles (3·2 km.) east of the centre of the district, flattens out and disappears by meeting the syncline on the north; it pitches to the west at an angle great enough to completely conceal the Goldenville formation by the Halifax slate formation at a distance of 5 miles (8 km.) west, and finally dies out also by joining the syncline two miles (3·2 km.) farther at Wellington station.

The anticlinal fold thus forms a long and narrow elliptical dome pitching to the east and west. In the western part of the dome the stratå on both limbs run nearly parallel with the axis of the anticline, but finally converge and curve sharply within 10 feet (3 m.) over the apex; towards the east the fold becomes gradually broader and the strata form nearly concentric curves.

The horizon of the quartzites and slates of the Goldenville formation exposed on the dome is estimated to be 4,560 feet (1,390 m.) below the base of the Halifax slate formation, and as the thickness cf the latter formation is 11,700 feet (3,566 m.), a total thickness of over 16,260 feet (4,956 m.) of strata has been eroded off the dome.

The dome has suffered much faulting especially in the eastern part. An important fault follows the axis of the anticline from the centre of the dome eastward, and attempts to trace veins around the apex of the dome past the fault have met with poor success. Radiating from the dome towards the southeast is a series of important faults, two of which have horizontal displacements of 112 and 124 feet (44

and 38 m.) respectively. On the north limb are a few small breaks. A few flat faults having the nature of thrusts have also been met in underground workings. The faults do not continue for great distance on the strike nor in depth and are later than the formation of the veins, but the Baker vein in the eastern part of the district occupies a fault plane cutting the anticline at right angles which is of earlier origin and probably greater extent in depth than the other faults.

CHARACTER OF THE GOLD DEPOSITS.

With the exception of the Baker vein which has been proved highly auriferous, all the veins worked in the district are of the interbedded type and are called leads. They follow fractures or slips along stratification planes and occur chiefly in beds of slate interstratified between beds of quartzite. The outcrops of the veins form almost complete concentric ellipses curving sharply at the western end and broadly at the eastern end of the dome. Over 25 interbedded veins have been worked and traced more or less continuously on both the north and south limbs of the dome. The vein-bearing zone is thus confined to the dome, on which it extends 8,100 feet (2,470 m.) east and west along the anticlinal fold and 1,600 feet (485 m.) across it.

The most productive part of the district is the eastern end of the dome, where the pitch of the anticline increases rapidly from 0° to 45°, causing there the maximum amount of fracturing across and along the stratification plane which produced rolls, corrugations and angulars favourable to ore deposition.

Amongst the most important interbedded veins may be mentioned the Dunbrack, Sterling, Boston-Oldham, North Wallace, South Wallace, and Donaldson. A great number of others have been worked and many of them with profit.

The most important ore-shoots follow the rolls, which are quite prominent in the veins in the southeastern part of the district and pitch to the east at approximately the same angle as that of the pitch of the anticline. On the Dunbrack lead a very persistent and rich ore-shoot was worked to a depth estimated at 1,200 feet (356 m.) on a pitch increasing gradually from 5° to 40°. The rich ore-shoot which in 1909 averaged 2·88 ounces of gold per ton in the Sterling Barrel lead on the apex of the anticline has been

worked to a depth of 1,610 feet (490 m.) on a dip varying from 30° at the surface to 43° at a vertical depth of about 900 feet (275 m.). This is the deepest mine on an interbedded vein in Nova Scotia.

In the northeastern part of the dome a number of veins such as the Boston-Oldham and Frankfort proved rich on their curve towards the apex of the anticline. Some veins have been worked extensively on the strike but to shallow depth.

North of the centre of the dome, several leads were enriched and thickened at the intersection of angulars entering obliquely from the southwest or footwall side and leaving on the northeast. The enriched and thickened part of a lead comprised between the point of entrance of an angular and that of leaving, is generally less than 20 feet (6 m.) in length and 100 feet (30 m.) in depth, forming a small ore-shoot called gold or pay-streak. Several very rich gold-streaks have thus been formed on the Blue, Hall and other leads where intersected by the Britannia angular, the ore yielding from 1 to 100 ounces of gold per ton.

In the northwestern and southwestern part of the dome a few leads have also been enriched at the intersection of angulars coming in on the footwall side from the southwest and northeast respectively. In the Blackie vein the gold was concentrated in arsenopyrite pockets, some of which carried as much as 5 to 7 ounces of precious metal, and outside of these the vein had little or no value.

In 1892, J. E. Hardman, manager for the Napier company, sank a vertical shaft 113 feet (35 m.) deep on the anticline on Area 102, cutting at the apex seven superimposed saddle-veins that do not outcrop at the surface. Two of these were sufficiently auriferous to justify further development. This and similar developments in other districts point to the existence of a pay-zone extending to a considerable depth in which a succession of auriferous, interbedded, quartz veins of similar character and extent lies superimposed one above the other.

At a short distance west of Hardman's vertical shaft the Harrison, South Ohio and some other adjacent veins are thickened several times their usual size on the apex of the anticline where they curve sharply within 10 feet (3 m.) and form ore-shoots pitching west about 20°.

In the Hay lead lying outside of the district, 1,800 feet (550 m.) north of the anticline, an isolated pocket carrying

60 ounces of gold was found at the intersection of an angular with the main lead.

A pocket of 100 pounds of reddish scheelite was found at the depth of 40 feet (12 m.) in a large roll of quartz in the Schaffer Barrel lead on the eastern pitch of the anticline, where good examples of barrel quartz structure can be observed at the surface. Smaller pockets are also reported to have been found in the South Wallace, Dunbrack and a few other veins. Until recently the mineral was not identified by the miners who called it pinkeye, and as gold is not found associated with it they shunned its presence.

PRODUCTION.

Gold was first discovered in this district in 1861. Active mining operations commenced the following year and have continued steadily to the present time. The official reports show that the yearly production of gold fluctuated between 282 ounces in 1897 and 3,171 ounces (for 9 months) in 1893, and the average yield per ton varied from 10 dwt. 21 gr. in 1881 to 3 oz. 5 dwt. 5 gr. in 1908.

The total gold production from 1862 to 1912 has been 67,343 ounces, valued at $1,279,520, extracted from 58,735 tons of ore. The average yield per ton is therefore 1 oz. 2 dwt. 22 gr.

ANNOTATED GUIDE: ENFIELD TO WESTERN END OF OLDHAM GOLD DISTRICT.

Miles and Kilometres.	
0 m. 0 km.	**Enfield Station**—Alt. 63 ft. (19·2 m.). Going in a southerly direction from Enfield station, the road runs for the first half a mile over flat-lying Lower Carboniferous sediments consisting chiefly of thick deposits of gypsum and beds of limestone, sandstone and shale which are here concealed by boulder clay and deposits of sands and clays of Pleistocene age.
0·5 m. 0·8 km.	**Shubenacadie River**—Alt. 47 ft. (14·3 m.). At the Shubenacadie river the road enters the Goldenville formation of the Goldbearing

Miles and Kilometres.

series, an area of Pre-Cambrian rocks which extends southward to the Altantic. For the first mile and a half, an ascending section of alternating beds of quartzite and shale, striking east and west, and dipping south at high angles, is traversed to a point 400 feet (120 m.) north of Lily lake, where the intervening syncline between the Shubenacadie-Grand lake anticline and the Oldham anticline is crossed and can be located a short distance on left by several outcrops of quartzite curving on the western plunge of the fold.

2·5 m. 4·0 km. **Horn Brook**—Alt. 247 ft. (75·3 m.). In the next half mile the same strata are again crossed but in descending order, to the Oldham anticline which crosses Horn brook 100 feet (30 m.) above the fall on the right. The Dowell lead may be observed on the left in an open-cut 200 feet (60 m.) north of the fall.

ANNOTATED GUIDE: OLDHAM GOLD DISTRICT.

(See plan and sections of Oldham Gold District).

Feet and Metres.

0 ft. 0 m. **Horn Brook**—Alt. 247 ft. (75·3 m.). From Horn brook at the western extremity of the district, the anticline strikes easterly along a ridge which is followed by the road as far as Black brook. Going easterly along the road, the following observations may be made reckoning the distances in feet from Horn brook.

1,500 ft. 457 m. Anticline exposed crossing road obliquely from right to left; apex plunges west about 20°; strata curve and dip north and south at low angles increasing rapidly to 70° to form a transversely symmetrical and sharp fold. Cleavage is perpendicular.

1,700 ft. 518 m. North of road 65 feet (20 m.) the South Ohio lead dipping south 43° and the Richey lead dipping north 35° follow the stratification and converge towards the west and in a sharp

Feet and Metres.

curve on the anticline to form one saddle-vein, the apex of which plunges westward about 20°. An ore-shoot on the apex containing arsenopyrite and galena 20 to 24 inches thick was worked only for a short distance on the pitch.

2,330 ft. 710 m. North of road 90 feet (27 m.): Harrison lead dipping north 55° curves conformably with the strata within 10 feet on anticline and forms another ore-shoot at the apex pitching westward about 20° and underlying the South Ohio-Richey ore-shoot; much galena; angulars entering from footwall side have thickened the lead at the apex. On both the north and the south limb of the anticline, a series of 25 interbedded and parallel veins outcrops within a distance of 800 feet (24·5 m.) which is the width of the auriferous quartz zone on each side of the axis; the two series of veins converge towards the west; several short ore-shoots called gold-streaks have been found in these veins, particularly on the north limb, at the intersection of angulars entering on the foot-wall side from the southwest on the north limb and from the northeast on the south limb.

2,590 ft. 789 m. North of the road 60 feet (18 m.): J. E. Hardman's vertical shaft 113 feet (42·5 m.) deep sunk on the axis of the anticline cut seven superimposed saddle-veins, both legs of which were intersected at a depth of 100 feet (30 m.) by cross-cuts driven 100 feet each way, showing the continuance of the saddle-veins to that depth and their conformity to the structure of the fold.

3,320 ft. 1,010 m. Alt. 313 ft. (95·3 m.). Goff's road leads off to right: centre of dome is reached; the anticline crosses from left to right and passes between the road and the school house, where beds of quartzite and slate are exposed lying horizontally along the apex and overlying the crest of a rich corrugated saddle-vein which

Feet and Metres.

was worked to some depth on both legs; the vertical cleavage is strongly developed even in the quartzite, and indicates the exact direction of the anticline; the intersection of the cleavage and bedding planes is at right angles indicating the centre of the dome. Large barren veins of coarse white quartz cross the anticline at right angles, and are probably the result of the arching of the fold producing the east and west pitch. At the foot of the hill, 125 feet (38 m.) north of the anticline, the footwall of a small lead adjacent to the Harrison lead dips north 65° and is also intersected by the same large cross veins; the lead is largely made up and enriched by very small angulars entering from the footwall side, but is not affected by the large cross veins. The strata and interbedded veins on both limbs strike parallel with the axis of the anticline.

4,090 ft. 1,247 m. Road runs downhill: close by on the right the footwall of the Morell lead curves slightly and dips north 57°; corrugations on the footwall caused by the intersection of cleavage and bedding planes pitch easterly at a low angle indicating the pitch of the dome. On the footwall is a fault having a horizontal displacement of 15 inches.

4,345 ft. 1,313 m. Close by on the left is W. A. Brennan's stamp-mill with 2 batteries and amalgamating tables, one Wilfley concentrating table, water-power. Footwall of a vein dips north 52°, corrugations pitch east.

4,540 ft. 1,383 m. **Black Brook**—Alt. 244 ft. (74·3 m.). J. E. Hardman's old stamp mill on the right, with 2 batteries and amalgamating tables, water-power and Pelton wheel, has produced probably more than half the gold extracted from the Oldham deposits. On the east side of Black brook, opposite the mill, a good section of the anticlinal fold is exposed where superimposed beds of quartzite and slate curve broadly on the apex; between a bed of slate and quartzite is intercalated a small vein, deeply corrugated, showing gold at the point of intersection of an

Feet and Metres.

angular. Vertical cleavage is strongly developed in the quartzite, the slipping along the cleavage plane having produced the corrugations, the slate besides being cleaved shows a sympathetic folding with the corrugations of the veins; the corrugations pitch eastward in the same direction as the pitch of the anticline. From Black brook eastward the pitch of the anticline increases gradually to 45°, the fold becomes broader and the strata describe large and almost concentric curves. Several faults radiate toward the east and southeast, the largest one following approximately the anticlinal axis.

Going easterly from Black brook over the hill in the direction of the anticline the following observations may be made.

4,790 ft. 1,460 m. At the top of the hill, on the south limb, the Carpenter lead curves in the shape of an S in a subordinate crumple of the strata, 14 feet wide, pitching east about 30°; the crumpled part of the lead is enriched and enlarged from 3 inches to 24 inches by angulars entering from below and forming a rich ore -shoot which was worked out to the depth of 200 feet (60 m.). The adjoining strata are conformably crumpled.

Farther east, the Galena, Boston-Oldham and other leads are crossed in open-cuts on the north limb of the fold where they curve to the anticlinal fault, on the south side of which they have not been identified.

5,840 ft. 1,790 m. On the Sterling Barrel lead, a rich ore-shoot has been worked to a depth of 1,610 feet (487 m.) by an inclined shaft on a dip increasing from 30° at the surface to 43° at a vertical depth of about 900 feet (275 m.); the ore-shoot occurs immediately south of the anticlinal fault, where the strata form a pronounced bulge or undulation of small horizontal width, but of great extent in depth; the structure and character of the shoot was very regular from the surface to the bottom of the workings, its horizontal length varying from 100 to 150 feet (30 to 45 m.). The vein is corrugated, lies on the lower side of

Feet and Metr s.

a bed of black slate and is often "frozen" to quartzite footwall in which the corrugations sink and form furrows.

Corrugations of the same character are well exposed 400 feet (120 m.) further east on the footwall of a shaft on the Rusty lead, which dips, 31° east and is supposed to be the continuation of the Sterling Barrel lead on the north side of the anticlinal fault.

Looking north from the top of the dump of the Sterling Barrel mine a good general view may be had of the workings along the outcrops of the veins, showing the curvature of the north-eastern part of the dome.

From this point the road follows in a north-easterly direction, crossing successively the North Wallace, Rusty, Rutherford and Frankfort leads where they are worked more or less along their outcrops by open-cuts and shafts. A branch road to the southeast is then followed along and across the Blue lead, to the Schaffer Barrel lead. The Schaffer Barrel lead has here been worked to a depth of 200 feet (60 m.) and southward along the outcrop as far as the anticlinal fault. The quartzite footwall striking south on a broad curve and dipping east 45° is much corrugated in deep furrows; the furrows pitch eastward and occur along the line of intersection of cleavage and bedding planes and are apparently formed by the vertical movements of the rock along the cleavage planes. The vein and enclosing slate are crumpled into a series of corrugations or barrels conformable with the furrows. South of the shaft a pocket carrying 100 pounds of reddish scheelite associated with ankerite was found in the vein at the depth of 40 feet (12 m.) in a large roll of quartz. The Schaffer Barrel lead has a horizontal displacement of 150 feet (45 m.) on the anticlinal fault, 124 feet (37·6 m.) on the Whitehead fault and 112 feet (34 m.) on the next one south.

For a third of a mile farther east, a few other interbedded veins occur on the eastern pitch

Feet and Metres.

of the dome, but none have been very productive. The Baker vein, a quarter of a mile east, is, however, of especial interest as being the only one in the district that crosses the stratification for any considerable length and has proved very productive. It lies in a fault-plane which cuts the anticline at right angles, and, unlike the interbedded veins, it has much gouge and is very irregular in thickness and crooked in strike, The average thickness of the vein is 18 inches (0·45 m.), and the average yield of the ore 5 to 7 dwts. Several 100-ton lots gave $1\frac{1}{2}$ to 2 ounces. The vein cannot now be seen at the surface.

The Hardman mine is on the Dunbrack lead in a westerly direction from the Schaffer Barrel lead across the anticline. This lead lies on the footwall side of a bed of slate interstratified with quartzite dipping southeast 43° Apart from the rolls, the thickness of the vein varies from a fraction of an inch to 8 inches and may average 4 inches. The vein is corrugated and the corrugations pitch east 38° like those directly north on the footwall of the Schaffer Barrel lead. Two well-defined and parallel ore-shoots or rolls have been worked in the lead, the Ned McDonnell shoot and the Hardman shoot, pitching east at a lower angle than that of the corrugations. The upper one, the Ned McDonnell shoot, does not quite reach the surface but was worked for a length of about 850 feet (259 m.) on the pitch to the first fault of 112 feet (34 m.), beyond which it has not yet been discovered. The quartz and slate measured in vertical section 8 inches in thickness and 9 feet in breadth, having been thickened and enriched by small angulars entering from the footwall side.

The Hardman ore-shoot, which was probably the richest one worked in the province, lies about 140 feet (42 m.) below the Ned McDonnell roll and runs parallel with it. It does not reach the surface, but lies at a depth of about 175 feet, and a little east of the western end of the Ned McDonnell roll, where it originates like the latter

Hardman ore-shoot in the Dunbrack vein, showing section and top of corrugations. Oldham, N.S. 1897.

Feet and Metres.

in a small roll increasing in size and value as it pitches 5° to 40°. It has been worked continuously on the pitch for about 1,200 feet (365 m.) across the first fault and as far east as the Whitehead fault beyond which it probably extends farther but has not yet been discovered. On the first fault the roll has an upthrow of about 130 feet (39 m.) and a horizontal displacement to the south of 112 feet (34 m.). The thickness of the vein above and below the roll averages 4 inches, whereas it increases in the roll and varies from 8 to 22 inches and may average 17 inches. In the roll the quartz and enclosing slate have a decided rolly structure, and vertical sections of the roll have the form of an elongated ellipse, the length or height of which varies from 8 to 18 feet. Small angulars of quartz, sometimes associated with siderite and seldom over an inch in width, branch off from the roll into the quartzite foot and hanging walls. Angulars entering the roll from the hanging-wall had little or no effect on the richness of the ore, but those from the footwall side were decided feeders or enlargers of the quartz above them. It is important to note that the vein dips steeper below the roll than above it, producing a decided flexure of the strata which may account for the formation of the roll and the angulars during the folding process and the consequent slipping upward of one bed upon another. Outside of the roll the ore had a general assay value of 3 to 15 dwt. (or $3 to $15) per ton in free gold, whereas the ore of the Hardman roll itself never yielded less than one ounce per ton, most of it gave 9 to 30 ounces, and sometimes as much as 80 ounces ($1,600) per ton for lots of 8 to 10 tons. The high grade ore was associated with galena and zincblende, the poorer quartz carrying from 1½ to 2 per cent of arsenopyrite, pyrite and pyrrhotite, all of these minerals being found also in the rich ore but subordinate in amount to the galena and blende.

Following the road out from Hardman's mine the southeastern part of the dome is traversed in a northerly direction to the anticline. First the Dunbrack, Schaffer Barrel and Ned McDonnell leads are successively crossed where they originate between the strata as these strata begin to curve to the northeast and to dip at lower angles towards the anticline, accompanied with a development of corrugations on the footwall. Then, from the Sterling Barrel lead to the anticline the strata curve more rapidly and the interbedded veins become more numerous and are greatly thickened by large barren 'bull' veins. The original structure of the strata and interbedded veins is, however, much disturbed by the faults radiating from the centre of the dome towards the southeast.

ANNOTATED GUIDE.

ENFIELD TO TRURO.

(G. A. Young.)

Miles and Kilometres.	
0 m. 0 km.	**Enfield**—Alt. 63 ft. (19·2 m.). Beyond Enfield the railway alternately approaches to and recedes from the Shubenacadie river. To the southeast, beyond the river rises a somewhat broken hilly country underlain by the rocks of the Goldbearing series. The Carboniferous area stretching to the north is lower and only gently undulating. Rock exposures are comparatively rare over the Carboniferous area but the presence, in many localities, of beds of gypsum and limestone indicates that the strata belong to the Windsor series. The beds are faulted and dip in various directions but usually at comparatively low angles.
12·4 m. 19·9 km.	**Shubenacadie Station**—Alt. 66 ft. (20·1 m.). The boundary between the area underlain by the Carboniferous strata and that occupied by the rocks of the Goldbearing series lies about 4 miles (6·4 km.) to the east. There the basal members of the Carboniferous are conglomerates and sandstones which in places contained sufficient alluvial gold to warrant mining. The

Miles and Kilometres.

source of the gold was, undoubtedly, the quartz veins of the underlying Goldbearing series.

Just beyond Shubenacadie station the railway crosses to the east side of Shubenacadie river and for upwards of a mile runs in view of the winding river. Beyond this point the railway gradually passes away from the river.

16·9 m. 27·2 km. **Stewiacke Station**—Alt. 86 ft. (26·2 m.). Beyond this station the railway approaches the banks of Stewiacke river, a westerly flowing tributary of Shubenacadie river. About 1½ miles (2·4 km.) beyond, the railway crosses the Stewiacke river and there leaves the valley of this river. The Stewiacke river drains a wide expanse of gently undulating country stretching far to the eastward and underlain by Carboniferous measures belonging to the Windsor series.

26 m. 41·8 km. **Brookfield Station**—Alt. 102 ft. (31·1 m.). Brookfield is situated near the northern boundary of the broad area of Carboniferous strata (Windsor series) crossed by the railway after leaving the region underlain by the Goldbearing series. In the districts about Brookfield, the Windsor beds dip in various directions at all angles.

Three quarters of a mile (1·2 km.) beyond Brookfield, the railway enters a district underlain by the Union series of Devonian or possibly Carboniferous age. The country is low and gently undulatory in character. Two and one quarter miles (3·6 km.) farther, the railway crosses a low summit (altitude, 181 feet or (155·2 m.) and commences the descent of the slopes leading to the Bay of Minas.

The strata belonging to the Union series dip in various directions at angles ranging from vertical to nearly horizontal. As in the case of the Windsor beds to the south, there is a general tendency for the strikes of the strata to pursue an easterly course. Presumably both groups of strata are closely folded along east-west axes and probably they are much faulted.

Miles and Kilometres.

On stratigraphical grounds, Fletcher concluded that the Union beds underlie the Windsor strata and therefore he considered them to be of Devonian age. In neighbouring districts, however, the Union and associated strata carry a flora of mid-Carboniferous (Millstone Grit?) age.

As the railway descends to the valley of Salmon river which flows westerly into the head of the Bay of Minas, the high hills of the Cobequids become visible to the north. These hills are flanked by disturbed Carboniferous strata which, in the valley of Salmon river, are overlapped by horizontal, Triassic sandstones and conglomerates. Truro is situated in the Triassic area, on the southern side of Salmon river and the boundary between the highly disturbed Union beds and the undisturbed Triassic, passes through the southern outskirts of the town.

34 m. 54·7 km. **Truro**—Alt. 60 ft. (18·3 m.).

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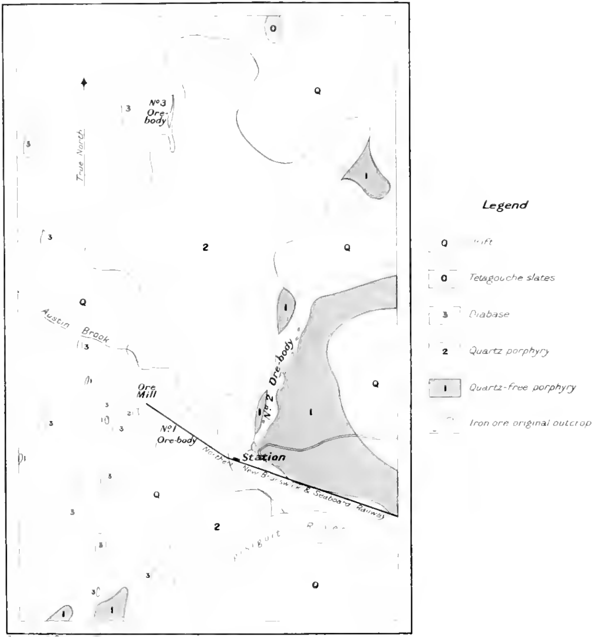

Geological Survey, Canada

Bathurst Iron Mine

Feet

Metres